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A GRAPHIC METHOD OF CORRELATING FISH ENVIRONMENT AND DISTRIBUTION

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It is some years since ornithologists saw the advantages of a graphic means of representing complex bird waves and their coincident relation to physical conditions. In ichthyology a schematic method whereby fish distribution and environment can be correlated is not less valuable.

The study of a stream and its fishes involves the consideration of factors so numerous and so diverse, and accumulates such a mass of data, that one is impelled to adopt some graphic method to make results appear quickly and clearly.

The chart to be described presently (Fig. 1) is of a hypothetic stream, including a variety of possible conditions. The first continuous vertical line to the right of the list of species represents the mouth of the stream, and the corresponding vertical on the right of the chart is its source. The dotted verticals numbered below (1–8) mark mile points. Beneath the "Misc. Data" space, these mile lines are not dotted but continuous.

The heavy horizontal opposite each species indicates the range of that species in the stream. Wherever the horizontal is broken, it indicates the occasional occurrence of the species. Whenever a species gains entrance to a stream from two or more points an arrow tip at the end of each of its range lines indicates the direction of its migration; *e. g.*, in our hypothetic stream the carp, *Cyprinus carpio* enters from the mouth and from canal overflows.

The continuous horizontal above the first species in the list, represents the surface of the water. The bottom is shown by the curved line labeled "Bottom of Stream." The average depth

at any given point is, therefore, the vertical between these two lines, read from the scale at the extreme right of the chart.

The continuous horizontal immediately below the last species enumerated, represents the altitude of the mouth above sea-level. The profile line indicates the drop in the stream. The approximate altitude of any given point along the stream is shown by the vertical between the two above mentioned lines, and read from the scale at the right.

The continuous horizontal in "Valley Cross Sections" represents the stream, on either side of which is shown a section of the country for one and a quarter miles. In these cross sections at every mile point the geologic formation can be indicated.

The current, width and bottom data are self explanatory. In the "Miscellaneous Data," bridges, marshy regions, dams, etc., are represented so far as possible, by the conventional signs employed by the U. S. Geological Survey, thus:

Bridges............(A)	*e. g.*,	below the one mile mark, at the two mile mark, etc.
Woodlands.........(B)	"	at the one mile mark.
Swamp............(C)	"	between the one and two mile marks.
Important Tributary (D)		represented by a forked wavy line. The position of the tributary line in the upper or lower part of the "Misc. Data" space indicates that the tributary enters the stream from the right or left side respectively.
	"	at the 1.25 mile mark. (Enters from the left side.)
	"	at the 2.6 mile mark. (Enters from the right side.)
Falls...............(E)	"	on either side of the four mile mark.
Dams..............(F)	"	at the 5.6 mile mark.
Remains of a Dam..(G)	"	at the seven mile mark.
Small Tributary.... (H)		represented by an unforked wavy line.
	"	at the 5.8 mile mark. (Enters from the right side.)

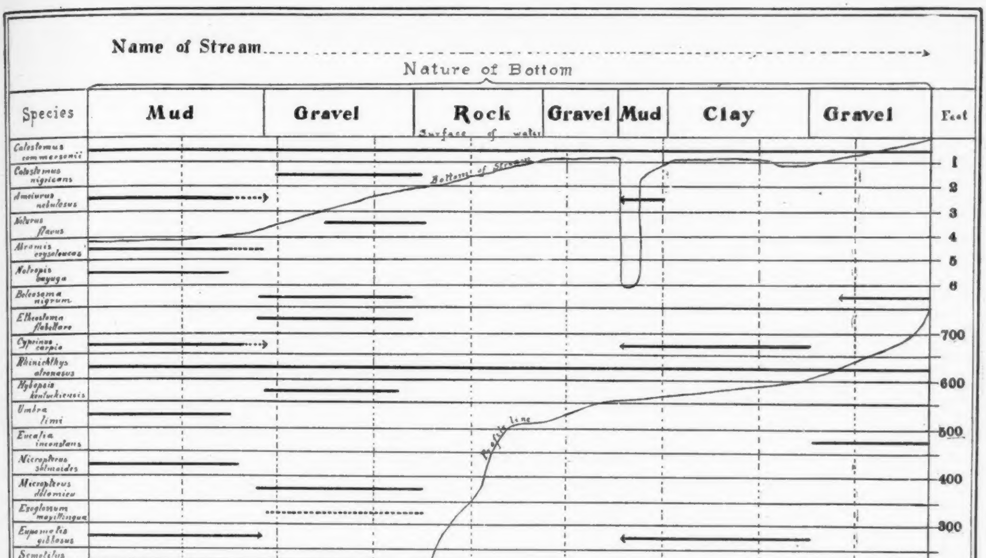

Fig. 1.— A Hypothetic Chart Correlating Fish Environment and Distribution.

Explanation of Miscellaneous Data.

A......Bridge.	F......Dam.
B......Woodlands.	G......Remains of a Dam.
C......Swamp.	H......Small Tributary.
D......Important Tributary.	I......Canal.
E......Falls.	

e. g., at the 7.25 mile mark. (Enters from the left side.)

Canal..............(I) " at the 7.5 mile mark.

Taking the common bullhead, *Ameiurus nebulosus*, as an example, one is able to read from the chart, concerning its distribution, etc., the following: it is common in the lower two miles of the stream, gradually decreasing in abundance at the end of the second mile. Throughout the middle course where rock or gravel bottoms and swift water or rapids occur this species is absent. In the upper course where the current and bottom are influenced by the dam, located 5.5 miles from the mouth, it reappears. In the latter instance, its presence so near the headwaters is due to canal overflows at the 7.5 mile point. It seldom frequents water less than 4 feet deep. In both ranges, the drop in the stream is slight, so that the current is just perceptible at the mouth, and imperceptible at the dam. At these two points the stream's width is respectively 27 and 32 feet. In both places a muddy bottom obtains. In the lower course the stream lies on a delta formation while in the upper course the underlying stratum is glacial drift.

The Johnny darter, *Boleosoma nigrum*, occurs at the source of the creek, due to a contribution at floodtime from another stream across the divide, the two sources being on the same level and continuous at some seasons. The falls on either side of the 4 mile point would preclude its reaching the source from the mouth.

One objection to the chart, which appears serious at first, is its failure to show migration within the stream. If a stream, however, be charted in this way in the spring, summer and autumn and a comparison of the three charts be made, many interesting deductions might be drawn. Should it seem desirable to make the work more intensive, to restrict it to a limited portion of a stream and to a single species, daily surveys might be made and the results embodied in one chart. The date of each daily survey could be placed in the spaces now occupied by the specific names and the range line for the day constructed opposite the date.

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THE MICROGAMETOPHYTE OF THE PODOCARPINEÆ[1]

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Although at the present time the views in regard to the relationships of the Coniferales depend very largely on the study of their gametophytic or sexual generation, our knowledge in regard to the gametophyte of the coniferous families is often very meager. The two families concerning which information is actually most needed are the Podocarpineae and the Araucarineae, exotics confined chiefly to the southern hemisphere. There is a prospect that our ignorance in regard to the Araucarineae will soon be less dense than it is at present, a consummation devoutly to be desired on account of the prevailing views, which make them the most ancient of the Coniferales. It is proposed in the present article to describe certain features of the male sexual generation of the Podocarpineae observed in material which we owe to the kindness of Dr. Cockayne of Christchurch, New Zealand, and Dr. Treub, Director of the Royal Gardens at Buitenzorg, Java. To both of these we tender our very warm thanks for the unfailing good nature which has made it possible for us to study some of the Australasian genera of the Podocarpineae. The material at our disposal was fixed in formaline or alcohol and consequently leaves something to be desired in the preservation of cytological details. As we shall however confine ourselves to the gross features of nuclear structure which do not suffer seriously by the methods of preservation described, this will not be a serious disadvantage.

The first species to be considered is *Podocarpus polystachya*, material of which we owe to Dr. Treub, Director of the Botanic Gardens at Buitenzorg. The male cones in our possession are in various stages of anthesis; but some of them show quite young anthers or microsporophylls in the upper region of the axis. This feature has made it possible for us to follow step by step the development of the male gametophyte up to the time of the shed-

[1] Contributions from the Phanerogamic Laboratories of Harvard University. No. 8.

ding of the pollen or microspores, in spite of the fact that the material represents a single collection. *A* figure 1, represents the first mitosis in the microspore, which it will be observed is well advanced toward completion. The state of preservation of this material is remarkable in view of the fact that it was fixed in strong alcohol. In *b* figure 1, is to be seen the first prothallial cell fully formed and lying over against the upper or *posterior* side of the microspore. Beneath it, is the residual nucleus surrounded by vacuolated protoplasm. In *c* figure 1, is to be seen the mitosis which precedes the formation of the second prothallial cell. In *d*

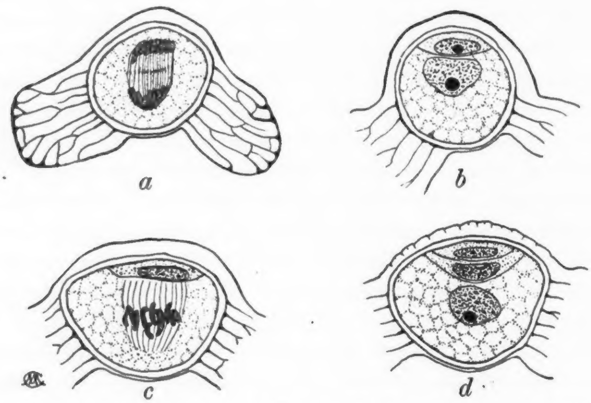

FIG. 1.— *Podocarpus polystachya*. *a*, First division of microspore. *b*, First prothallial cell cut off. *c*, Cutting off of second prothallial cell. *d*, Two prothallial cells cut off. × 925. The lateral air chambers, completely shown in *a*, are one of the numerous features of resemblance between the pollen of the Podocarpineæ and that of the Abietineæ.

figure 1, the second prothallial cell is complete and lies against the first. At about this time the strongly thickened posterior wall of the microspore, which seems to be a peculiar feature of podocarpineous pollen, becomes markedly sculptured as is shown in *d*. In *a* figure 2, is shown a still later phase where the so-called generative cell has become added to the prothallial cells, which lie on the posterior wall of the microspore; it arises from another division of the residual nucleus. The contents of the pollen grain at this stage resemble in detail the conditions to be found in the abietineous microspore before the prothallial cells have begun to degenerate.

In Podocarpus however there is no atrophy of the prothallial rudiments at this stage, but they undergo further changes of a surprising character, comparable only to those recently described by Thomson[1] in the genus Araucaria. In *b* figure 2, a later stage of development is shown, in which each of the prothallial cells has undergone transverse or anticlinal division. Division generally takes place first in the outer prothallial cell lying next the wall

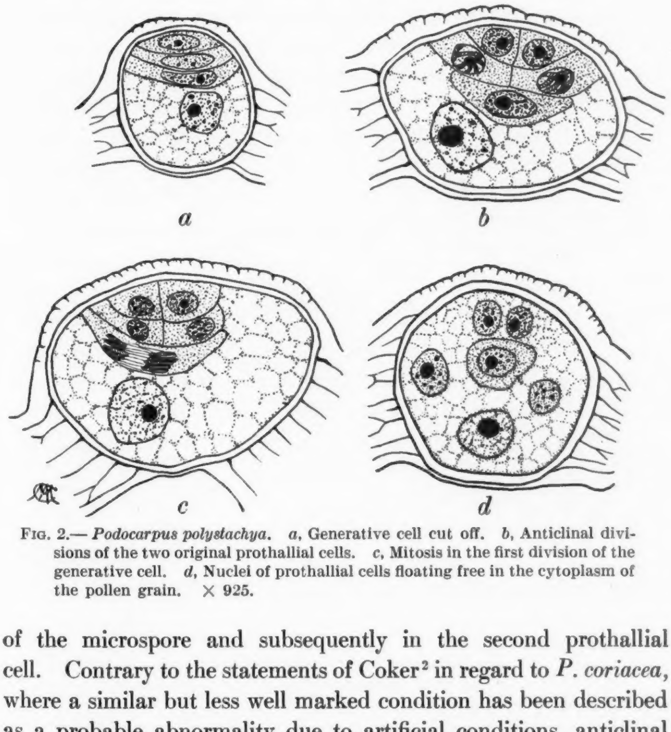

FIG. 2.— *Podocarpus polystachya*. *a*, Generative cell cut off. *b*, Anticlinal divisions of the two original prothallial cells. *c*, Mitosis in the first division of the generative cell. *d*, Nuclei of prothallial cells floating free in the cytoplasm of the pollen grain. × 925.

of the microspore and subsequently in the second prothallial cell. Contrary to the statements of Coker[2] in regard to *P. coriacea*, where a similar but less well marked condition has been described as a probable abnormality due to artificial conditions, anticlinal divisions of the prothallial cells are not initiated by direct division of the nucleus but by true mitosis. In the cells derived from

[1] Thomson, R. B. The Araucarieæ — a 'Proto-Siphonogamic' method of Fertilization. Science N. S. **25**: 271, 272. 1907.

[2] Coker, W. C. Notes on the gametophytes and embryo of Podocarpus. Botan. Gazette **33**: 89–107. pls. 5–7. 1902.

the second prothallial cell in *b* figure 2, the nuclei are still in the spireme condition. Occasionally anticlinal divisions occur in the generative cell as in the prothallial rudiments. One such case is represented in *c* figure 2, which is an obvious and clear mitosis. Usually however in *P. polystachya* such divisions of the generative cell do not occur, although they are exceedingly common in some of the other species which we have had the opportunity of studying. At about this time the prothallial cells lose their walls; and their nuclei, floating freely in the cavity of the microspore, are no

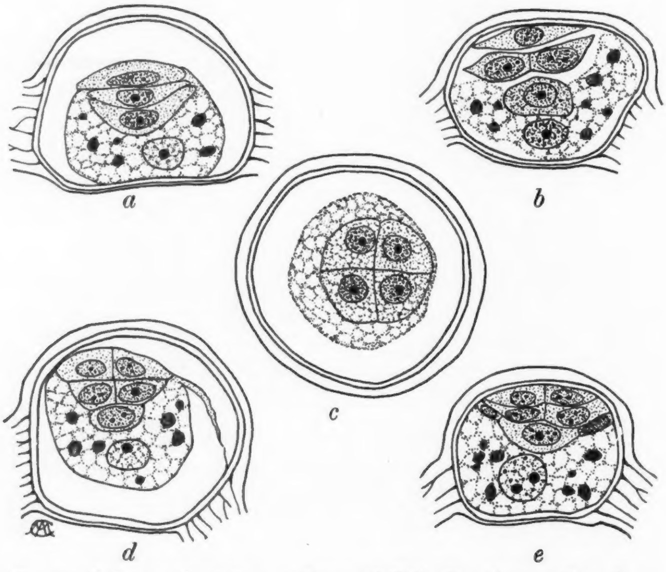

FIG. 3.— *Podocarpus ferruginea*. *a*, Two prothallial cells and generative cells formed. *b*, Anticlinal divisions of second prothallial cell. *c*, Tangential view of prothallial end of the gametophyte. *d*, Anticlinal divisions of both prothallial cells. *e*, Divisions in prothallial and generative cells. × 925.

longer enclosed by cytoplasmic bodies. The nuclei, however, persist indefinitely and pass out as a swarm into the pollen tube. Among the unusually numerous free nuclei present in the microspore at this stage, the residual or tube nucleus can be distinguished readily by its large size, as is shown in figure 2 *d*; the generative cell, or the central cell derived from it in case it has undergone

anticlinal divisions previous to being set free from the prothallial complex, always retains its protoplasmic body as is generally the case in other Gymnosperms, and thus cannot be confused with any of the other contents of the microspore in the condition which immediately precedes anthesis.

In *Podocarpus ferruginea* from New Zealand, material of which we owe to the kindness of Dr. Cockayne, the earlier stages are not so well represented as in the species described above, but so far as they have been followed they present no essential deviation from the course of events in *P. polystachya*. *A* figure 3, represents the abietineous stage of development in this species. The preservation is even less good than that of the Podocarpus already described, and the protoplasm has shrunken from the microspore membrane. In *b* figure 3, is shown a fully developed grain, in which only one of the prothallial cells has undergone division. The generative cell in this case is also free from divisions, although it has rounded off and is almost ready to be set free from the cavity of the microspore. *C* figure 3, presents a tangential view of the first prothallial rudiment, which in this case has undergone two anticlinal divisions, so that four cells have resulted. *D* figure 3, presents a longitudinal section through the air chambers and shows anticlinal divisions in both of the prothallial cells. *E* figure 3, shows a similar condition in the prothallial rudiments; but in this case there are two lateral derivatives of the generative cell. The latter are very small in size compared with the central cell of the generative complex and with the derivatives of the prothallial rudiments.

As is represented in figures 3 and 4, starch is commonly found in the pollen grains, especially in the younger stages, though its presence is by no means constant. A similar feature has been noticed by Coker in the article cited above.

A figure 4, shows the structure of a ripe pollen grain in *P. dacrydioides*, from material sent us by Dr. Cockayne. The conditions are identical with those shown in *e* figure 3, representing *P. ferruginea*.

B figure 4, shows the gametophytic development in a probably mature microspore of *Dacrydium Bidwillii*, another representative of the Podocarpineæ. The material in this case proved to be

very badly preserved. Dacrydium is distinguished from Podocarpus by the transverse striations of the thickened posterior wall of its microspore. In the species of Dacrydium which we have examined more than two prothallial cells are present, but the derivatives of the prothallial rudiments do not seem to be as numerous as they are in Podocarpus, where there may apparently be as many as eight present (*P. ferruginea*).

Through the kindness of Dr. Cockayne we have had the opportunity of comparing the microgametophytic development of Podocarpus and Dacrydium with that presented in Agathis, probably the more ancient of the two living genera of the Arau-

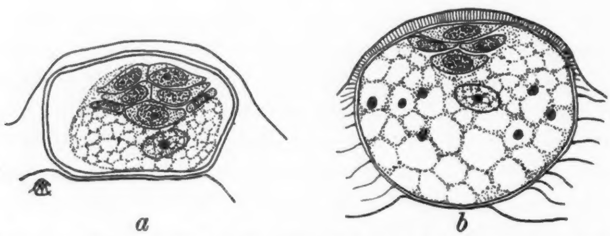

FIG. 4.— *a Podocarpus dacrydioides*. Divisions of prothallial and generative cells. *b, Dacrydium Bidwillii.* The second prothallial cell has divided. × 925.

carineæ. In our material of Agathis the protoplasm is unfortunately very much shrunken, possibly on account of the small amount of alcohol in which it was preserved, but this fortunately does not interfere with the understanding of the general conditions present in the microgametophyte. In *b* figure 5, is shown an apparently mature microspore. We cannot however speak with certainty on this point, since none of the microsporophylls in our possession have shed their pollen. It is to be noted that the conditions present in this figure closely resemble those depicted in *b* figure 2, and *d* figure 3. In other words there are subsequent anticlinal divisions present in the two prothallial rudiments which are originally laid down as they are in the Abietineæ. *A* figure 5, resembles *b* closely and differs in the fact that only one of the prothallial rudiments has become divided. In *c* figure 5, is shown a tangential view of one of the prothallial cells. There have obviously been two anticlinal divisions in this case.

It is apparent from the foregoing paragraphs that in two genera of the Podocarpineæ there are unusually numerous prothallial cells present in the microspore, which are derived by the subsequent anticlinal divisions of the two primitive prothallial cells. That these features are perfectly normal ones in the Podocarpineæ is made clear by the fact that all our material is from plants grown in their native habitat and presumably under natural conditions.

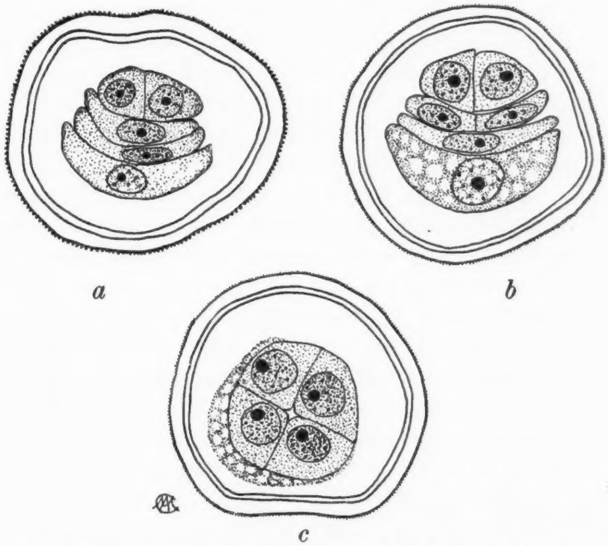

FIG. 5.— *Agathis australis.* *a*, The divided first prothallial cell, undivided second prothallial cell, generative cell, and tube nucleus. *b*. The same, but the second prothallial cell has also divided. *c*, Tangential view of the prothallial end of the gametophyte. × 925.

These features are further paralleled by the conditions presented by the microspore of the araucarian genus Agathis. The question here arises if we are to regard the rich prothallial endowment of the Podocarpineæ as the retention of a feature possessed by the ancestral Coniferales or as a recent cenogenetic adaptation, which has arisen at a later stage of evolution. This question can only be answered by a consideration of the microgametophytic conditions found in the Gymnosperms in general, particularly the more ancient of those still living. In the primitive zoidogamous

Cycads and Ginkgo there are one or two prothallial cells present. The generative cell undergoes only a tangential or periclinal division in connection with the formation of the stalk cell and antheridial cell. The antheridial cell in both the Cycadales and Ginkgoales gives rise to two spermatocytes, the mother cells of antherozoids. In the Abietineæ, which we know from the evidence of the fossil remains extend very far back geologically in forms allied to Pinus, there are two evanescent prothallial cells present in the mature microgametophyte, and a generative cell which as in the zoidogamous Gymnosperms gives rise to stalk and antheridial cells by periclinal division. The antheridial cell in turn gives rise to two cells which are to be regarded as the homologues of the two spermatocytes of the Cycadales and Ginkgoales. In the Araucarineæ, so far as our knowledge goes, there are formed at first two prothallial cells, which may subsequently undergo more or less numerous anticlinal and possibly also periclinal divisions. The final history of the generative cell is obscure, but it is to be inferred from the brief summary of Thomson (*loc. cit.*) that the antheridial cell of the Araucarineæ does not divide into two as in the Abietineæ and the ancient zoidogamous Gymnosperms. In the Araucarineæ there is a further remarkable feature in that the pollen grain does not reach the micropyle of the ovule as in the other Coniferales and all other known Gymnosperms living or fossil; but is deposited on some part of the ovuliferous scale or megasporophyll (on the 'ligule' in Araucaria) thence sending a pollen tube down to the ovule, in a manner analogous to that obtaining in the Angiosperms. Thomson, adopting the prevailing hypothesis that the Araucarineæ are the most primitive Coniferales, designates this peculiar mode of fertilization as primitive or 'protosiphonogamic.'

This view presents some difficulties, for if the quasi-angiospermous method of fertilization found in the Araucarineæ is 'primitive' it is difficult to see why such a method is entirely absent in the older gymnospermous series, the Pteridospermæ, Cordaitales and Ginkgoales, or being ancestral for the Coniferales is entirely lost in the coniferous families other than the Araucarineæ, which have moreover a method of pollination resembling closely that of the older Gymnosperms in that the microspores are received through the micropyle. The reported presence of only a single

sperm-cell in the Araucarineæ supplies another argument against their being more primitive than the other Coniferales. Their superior antiquity further does not rest on any sound palæontological basis, for so competent an authority as Schenk (Zittel's Handbuch) remarks that if more abundant and more ancient geological occurrence were to be considered as a criterion of antiquity, the Araucarineæ must yield place to the Taxodineæ. It appears not unlikely, especially in view of observations made by one of us on Mesozoic Coniferales, shortly to be published, that the 'protosiphonogamic' method of fertilization which is the interesting discovery of Mr. Thomson, is correlated with the proliferation of the prothallial cells in the Araucarineæ, since the greater length of pollen tube, in the absence of any special conductive tissue such as is found in the Angiosperms, calls for a greater development of prothallial tissue. The failure of the pollen to reach the micropyle, on the other hand, may have been due to the unfavorable influence of drought upon the fluid secretion which in other Conifers floats the pollen to the micropyle.

Turning from the Araucarineæ to the Podocarpineæ, we find very similar conditions in regard to the prothallial proliferations. The plan of prothallial development here as in the Abietineæ and Araucarineæ involves two prothallial cells, but as in the Araucarineæ these have apparently undergone cenogenetic proliferation. That this is the true view of the matter is rendered more probable by the fact that even the generative cell may be affected by the process of proliferation, as in *Podocarpus polystachya*, *P. ferruginea* and *P. dacrydioides*, described above. There is certainly no reason from our knowledge of the older and zoidogamous Gymnosperms to regard the anticlinal proliferation of the antheridial cell as a primitive feature, since so far as our present information goes such a phenomenon is quite absent here. Further whatever prejudice there may exist in favor of the Araucarineæ being a primitive family of Conifers, there can be none in favor of a like view in the case of the Podocarpineæ. The development of the microgametophyte in the case of the Podocarpineæ as here described only serves to strengthen the opinion already expressed by Coker (*op. cit.*) and Thomson[1] that they are not

[1] Thomson, R. B. The megaspore-membrane of the Gymnosperms. Univ. of Toronto Studies, Biological Series No. 4. 1905.

very remotely connected with the Abietineæ. Their peculiar prothallial developments represent an apparently cenogenetic superaddition to the primitive type of coniferous microgametophyte found in the Abietineæ. If this view be taken of the position of the Podocarpineæ, it may well be extended to the Araucarineæ which present a similar microgametophytic development, although it would take us too far afield and would involve the discussion of yet unpublished data in regard to living and fossil Coniferales, to defend that proposition in the present connection.

Summary

1. The Podocarpineæ as represented by the genera Podocarpus and Dacrydium are characterized by a proliferation of the two original prothallial cells through more or less numerous anticlinal divisions.

2. The anticlinal proliferation of the prothallial cells in some cases is accompanied by a similar proliferation of the generative cell, an abnormality which appears to have been described in no other Gymnosperms.

3. Similar proliferation of the two original prothallial cells has been observed in the araucarian genus Agathis.

4. The proliferation of the two prothallial cells in the Podocarpineæ and Araucarineæ and the proliferation of the generative cell in certain species of Podocarpus, cannot be regarded as a primitive feature.

5. The ground plan of microgametophytic development found in the Podocarpineæ and Araucarineæ points to their derivation from an ancestral stock allied to the Abietineæ.

6. Since the Podocarpineæ and Araucarineæ present many features of similarity in general habit, in geographical distribution, in the organization of their megasporophylls, and the development of their microgametophytes, it seems not improbable that they are somewhat more nearly allied than has been supposed.

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THE PROBLEM OF COLOR VISION

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THE problem of color vision is one of the most intricate which the biologist is asked to solve. The following paragraphs are intended to indicate the several methods which are being employed for its solution, together with some of the results thus far obtained. The anatomy of color vision will be considered first; then in turn its physiology and its development; and finally, the abnormal conditions of color blindness, together with the theories of normal vision to which they have given rise.

Anatomy. The mechanism of color vision is lodged in the rod and the cone cells. A ray of light, after passing through the lens of the eye and its vitreous body, penetrates several layers of the retina, thus arriving at the proximal ends of the elongated rod and cone cells. These cells are arranged in a single row. The light traverses the length of the cells to their distal ends which it stimulates. The rod and cone cells project against a single layer of heavily pigmented cells, the *stratum pigmenti retinae* (Fig. 1, S. P.). These have non-retractile processes which are found between the rods and the cones. The pigment fuscin, in the form of elongated or crystalloid granules, migrates into these processes when the eye is illuminated; in the dark it is withdrawn into the cell body.

Every rod cell consists of a rod, a rod fiber, and a nucleus, arranged as shown in Fig. 1, A. A rod, which is from 40 to 50 μ long and 1.5 to 2 μ in diameter, consists of a doubly refractive, lustrous *outer segment*, and a singly refractive, finely granular *inner segment.* In serum or dilute osmic acid the outer segment breaks into a series of regular transverse discs which are believed to indicate a stratified structure in the living rods. Visual purple is a pigment which occurs only in the outer segments of the rods.

It bleaches rapidly in the light, but (unless the pigmented stratum has been removed experimentally) it is soon restored in the dark. Light thus appears to incite chemical processes in the outer segments of the rods. The inner segments are sometimes described as having a longitudinally fibrillar structure in their outer portions. The opposite ends pass rather abruptly into the very slender rod fibers. Each fiber somewhere in its course expands to enclose the nucleus, and finally terminates in a pyriform enlargement. The nucleus in preserved specimens may have its chromatin arranged in a few broad transverse bands.

Every cone cell consists of a cone, a cone fiber, and a nucleus. The cones like the rods are divisible into outer and inner segments. The outer segment is usually shorter than that of the rod (12 μ) and tapers somewhat to its rounded extremity. It never contains visual purple, but otherwise, as for example in breaking into transverse discs, it resembles the outer segment of the rod. The inner cone segment bulges like the body of a flask. It is divided into an outer, longitudinally fibrillar, *ellipsoid* portion, and an inner contractile *myoid* portion. The non-contractile ellipsoid is said to become strongly eosinophilic in the dark. Because of the myoid substance the cones, unlike the rods, may alter their length. The contractility is said to be less in man than in the pig, and less in the latter than in some amphibia and fishes where the myoid segment is reported to shorten from 50 μ to 5 μ. The nuclei are found in a mass of protoplasm near the base of the cone; beyond the nucleus the protoplasm forms a cone fiber which is thicker than that of a rod and which ends in a branched and expanded base.

The stimuli received by the outer segments of the rods and cones are transmitted through their fibers to the nerve cells of the retina, and thence to the brain. A single retinal nerve cell receives the stimuli from several rods and cones.

Since rods and cones are believed to have different relations to the perception of color their distribution in man and other animals should be significant. In the peripheral portion of the human retina rods are in excess, so that in sections three or four rods appear between every two cones. Near the depression or *fovea* where vision is most acute, rods and cones are equally abundant,

and in the fovea itself only cones are found. These cones, however, are strikingly rod-like in form, and greatly exceed the rods in length (Fig. 1, B). Slender cones are also found in the thickened *area centralis* which in many mammals replaces the human fovea.

In the ape, horse, pig, cow, sheep, and dog the rods and cones are similar to those of man. In rodents which avoid the light the cones are "very small and hard to detect since their inner segments scarcely differ from those of the rods, from which they may be distinguished by their much shorter outer segment. M.

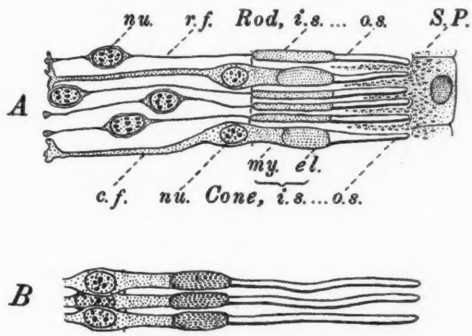

FIG. 1.— *A*, diagram of human rod cells and cone cells from the equatorial part of the retina. *B*, cone cells from the fovea, drawn on the same scale.

Schultze at first questioned the existence of cones in the mouse, guinea pig, mole, hedgehog, and bat. The cat undoubtedly has cones but they are small, slender, and except in the *area*, infrequent."[1] Birds have a single or double fovea, like that of man. Cones are small but very numerous, and in their inner segments they often contain a drop of oily substance, either colorless or various shades of yellow, green or red. Presumably these drops which are absent from the rods and some of the cones, exert an important influence upon color perception. In owls the bright colored drops are lacking and the cones are said to be fewer. Some reptiles have foveæ; two kinds of visual cells are reported, neither of which resembles the mammalian rods. M. Schultze

[1] The quotation, and much of this account of the retina, is from von Ebner's resumé in Koelliker's *Handbuch der Gewebelehre*, 1902, vol. 3, p. 818–832.

believed that reptiles have only cones. In fishes and amphibia, both rods and cones occur; in some sharks, rays, and eels, however, the cones so resemble rods that they may be overlooked. Whether or not deep sea fishes are without cones is apparently unknown. In the various groups of animals the rods and the cones each present modifications of structure, with which as yet physiological observations have not been correlated.

Physiology. The physiology of color vision is the study of the functions of the rod and the cone cells. In passing from a bright to a very dim illumination one experiences a momentary blindness; after becoming accustomed to the darkness, a modified form of vision is regained. In this *twilight vision* the fovea is far less sensitive to light than the more peripheral parts of the retina. Moreover all objects appear in shades of gray. The spectrum is bright but colorless, and its brightest part has shifted from the yellow portion toward the blue. Von Kries has explained these facts by assuming that the cones are the agents of day vision, and the rods of twilight vision.[1] Cones, exclusively, occur in the fovea where day vision is most acute; and rods predominate where twilight vision is at its best. The fluctuations in the visual purple of the rods show that they respond to the varying intensities of dim light, and this purple is known to desintegrate most rapidly in green light which appears brightest in twilight vision. Whether or not the bleached rods are active in day vision has not been determined.

It is probable that all cones do not respond to color stimuli. In the peripheral portion of the retina there is a partially color-blind region where red and green cannot be distinguished from one another; and the outermost portion of the retina is always totally color blind. Since cones occur in these areas they also must be color blind. From these considerations it is reasonably assumed that, in human vision, the ability to perceive colors depends upon the differentiation of certain of the cones.

Since at the present time the nature of vision cannot be determined by the microscopic examination of the retina, and since a very efficient vision may exist without color perception, it may

[1] Von Kries presents this *Duplizitätstheorie* in Nagel's *Handbuch der Physiologie*, 1904, vol. 3, p. 168–193.

fairly be questioned whether the lower animals are capable of color vision. The biological importance of this problem is very great, since prevalent theories of the development of the colors of flowers, and the bright plumage of male birds, assume a color perception in insects and female birds essentially like that in man. To learn what a bee actually sees has been thought impossible since it requires that one should possess the nervous system of an insect and still remain a man.

There is a large literature dealing with the distinctions which the lower animals make between various colors, but the factor of intensity or brightness has seldom been satisfactorily eliminated. The trout fisherman is confident that one fish, at least, discriminates colors with precision. Careful experiments with the chub, by feeding it from colored forceps and taking certain precautions to eliminate brightness, indicate that the chub distinguishes red from green and from blue.[1]

Nagel, who is convinced that the phenomena of mimicry and warning colors demand color vision in animals, experimented with the dog. After taking precautions to eliminate brightness, he proved that the dog perceived the difference between red and blue, blue and green, and red and green.[2]

Kinnaman tested the monkey, *Macacus rhesus*. Its food was placed in one of six receptacles, precisely alike except that each was of a different color. When the monkey had learned to choose correctly the food-containing glass, a different color was selected. Thus the monkey learned to proceed at once to the receptacle with food, whether it was blue, yellow, red or green. It was tested also with a black and light gray glass. Having learned that the food was in the former, successively darker grays were substituted for the empty one. The percentage of wrong choices increased and it was found that grays were confused which the human eye can distinguish with perfect ease and certainty. Kinnaman concludes that "there can be no doubt that monkeys per-

[1] Washburn, M. F. and Bentley, I. M. The establishment of an association involving color discrimination in the creek chub. *Journ. of Comp. Neur.*, 1906, vol. 16, p. 113–125.

[2] Himstedt, F., and Nagel, W. Versuche über die Reizwirkung verschiedener Strahlarten auf Menschen- und Tieraugen, *Festschrift der Albert-Ludwigs-Universität* in Freiburg, 1902.

ceive colors." Two colors of equal brightness are distinguished better than two grays of equal brightness; and though the brightnesses are the same, colors may be distinguished from grays.[1]

In the dancing mouse, however, the cones of which are at least very rod-like, Yerkes has recently found that color vision is extremely poor. There is some evidence of discrimination of red and green, and of red and blue, but none whatever of blue and green. Apparently such visual guidance as is received results from differences in brightness. The mouse discriminates blacks grays, and whites.[2]

Because of the inherent difficulties in the investigation of color vision in the lower animals, comprehensive results have not yet been obtained, but the newer methods promise notable discoveries.

Development. Since color vision is a complex differentiation, it might be expected that in the course of development, an individual should successively pass through the simpler stages by which it was acquired. Anatomically it has been shown that the retinal layers first become distinct at the center of the retinal cup, and that the differentiation of the retinal cells decreases from the center toward the periphery. In the chick it is said that the cone nuclei may be identified at an earlier stage than the rod nuclei,[3] but it is not generally recognized that one form of visual cell precedes the other.

The development of color vision has been theoretically considered by Mrs. Ladd Franklin.[4] Her theory assumes that the colorless sensations, white, gray and black, are caused by a primitive photo-chemical substance called the gray substance, which is composed of numerous gray molecules.

These gray molecules, which persist in their primitive state only in the rods, upon disassociation furnish us with the gray sensa-

[1] Kinnaman, A. J. Mental life of two *Macacus rhesus* monkeys in captivity. *Amer. Journ. of Psych.*, 1902, vol. 13, p. 98–148.

[2] Yerkes, R. M. The sense of vision in the dancing mouse. *Journ. of Comp. Neur.*, 1907, vol. 17, p. 194.

[3] Weysse, A. W., and Burgess, W. S. Histogenesis of the retina. *Am. Nat.*, 1906, vol. 40, p. 611–634.

[4] Franklin, C. L. On theories of light sensation. *Mind*, 1893, N. S. vol. 2, p. 473–489.

tions. In the cones the gray molecules have undergone a development such that a certain portion only of the molecule becomes disassociated by the action of light of a given color.

The differentiation of the primitive gray molecule is supposed to have taken place in three stages (Fig. 2). The first stage is represented by the simple, primitive gray molecule, so constructed that it is disintegrated by light of any color, thus producing a gray or white sensation. In the second stage the molecule is more complex and contains two groupings, the disassociation of one of which gives the sensation of yellow and the disassociation of the other gives blue. The simultaneous disassociation of both gives white. This stage persists in the peripheral portion of the retina where neither green nor red can be perceived as such. In the third stage the yellow grouping is divided to form two new combinations, the disassociation of one of which produces the sensation of green and the other the sensation of red.

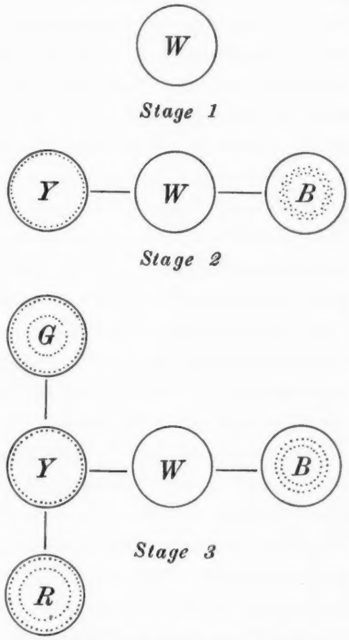

FIG. 2.— Diagram to illustrate the Franklin theory. The blue, green, and red groupings are represented by an outer, middle and inner circle of dots respectively. Disassociated groupings are omitted.

If the red and green groupings are disassociated together the resulting sensation is yellow; whereas the simultaneous disassociation of the red, green, and blue groupings produces the white sensation.

Schenck[1] has somewhat extended this theory by describing the development of the primitive gray molecule. Since in twilight

[1] Schenck, F. Über die physiologischen Grundlagen des Farbensinns. *Sitz.-ber. d. Gesell. d. ges. Naturw. z. Marburg.* 1907. Jahrg. 1906, p. 133–164.

vision the red end of the spectrum is lost, and the green-blue portion is its brightest part, he considers that the photo-chemical substance of the rods is attuned only to the green-blue light, which is perceived as colorless. Later this photo-chemical substance becomes sensitized in two stages, first to include the green-yellow, and then the yellow-red, which however are still perceived as colorless light. Thus a gray molecule like that of Mrs. Franklin's first stage is constructed. It occurs in the color blind peripheral cones. The formation of color-reacting groupings in the partly sensitized gray molecule leads, according to Schenck, to those forms of human vision in which the red end of the spectrum is shortened.

Observations upon the color perception of young children do not support these developmental theories. Holden and Bosse [1] tested two hundred children by placing before them square pieces of colored paper attached to a gray background of similar brightness. If the child made an effort to grasp the square, its color must have been perceived. It was found that the average child would react to all colors by the tenth month, the red end of the spectrum causing response a little earlier than the violet end. When ribbons of six spectral colors were placed before children of from seven to twenty-four months, red was selected first; orange or yellow second and third; and green, blue and violet last of all. Nagel [2] showed his child of twenty-eight months each of the spectral colors in varying degrees of brightness, at the same time teaching him their names. Red and green were learned easily, but blue was acquired with greater difficulty than any other color, including violet. Green, violet, and red were preferred; black, yellow, white, gray, and blue had secondary rank. Other experiments with the color perception of children have given different results. It is clear, however, that children are not known to pass from a color blind stage, through one of yellow-blue vision, to a discrimination of all the spectral colors. No race of men now exists in

[1] Holden, W. A. and Bosse, K. K. The order of development of color perception and color preference in the child. *Arch. of Ophth.*, 1900, vol. 29, p. 261–277.

[2] Nagel, W. A. Observations on the color sense of a child. *Journ. of Comp. Neur.*, 1906, vol. 16, p. 217–230.

which any of the colors is unknown; and the notion derived from studying the color terms and references in ancient literature, that man in historic times had a deficient color sense, is not substantiated. It may be that as in children, the red portion of the spectrum was preferred to the blue, but even this is not established.

Color blindness. All the colors which are normally perceived may be produced by combinations of the spectral red, green, and blue. Normal vision is therefore *trichromatic*. Sometimes in trichromatic vision the red end of the spectrum is shortened; in other cases a mixture of red and green, which to normal persons appears pure yellow, may seem tinged with red or green. Thus there are variations in trichromatic vision. Greater abnormalities may take the form of *dichromatic* and *monochromatic* vision. The latter is a rare pathological condition in which all colors are perceived as shades of one; vision therefore is essentially colorless (achromatic), the images obtained being comparable with photographs. In dichromatic vision color perception is so limited that all of the shades perceived may be made by combining two of the spectral colors red, green, and blue; blindness to the third of these colors may be partial or complete. The ordinary color blindness is dichromatic. Forty men and four women per thousand are either wholly unable to perceive certain colors or can recognize them only with difficulty. This defect is usually congenital and hereditary. It may cause so little trouble as to pass undetected until the age of seventy. All attempts to overcome the color blindness by educating the color sense in various ways, have failed.

Since dichromatic color blindness plays so large a part in the theories of normal vision, a portion of Dr. Pole's description of his own case is here inserted. He says,[1] "In the first place we see white and black and their intermediate gray, provided they are free from alloy with other colors, precisely as others do. (Such statements are confirmed by those who are color blind in one eye, the other being normal.) Secondly there are two colors, namely yellow and blue, which also if unalloyed we see, so far as can be ascertained, in the normal manner. But these two are the *only*

[1] Pole, W. Colour blindness in relation to the Homeric expressions for colour. *Nature*, 1878, vol. 18, p. 676–679.

colors of which we have any sensation. It may naturally be asked: Do we not see objects of other colors such as roses, grass, violets, oranges, and so on? The answer is that we do see all these things but that they do not give us the color sensation correctly belonging to them; their colors appear to us as varieties of the other color sensations which we are able to receive. Take for example the color red. A soldier's coat or a stick of sealing wax conveys to me a very positive sensation of color, by which I am perfectly able to identify, in a great number of instances, bodies of this hue. But when I examine more closely what I really see, I am obliged to conclude that it is simply a modification of one of my other sensations, namely yellow. It is in fact a yellow shaded with black or gray, a darkened yellow or yellow brown."

Dichromatic vision occurs in three forms, in two of which red and green are not differentiated from one another. The three forms are named *protanopia, deuteranopia,* and *tritanopia* respectively. In protanopia the red end of the spectrum is shortened; that is, a portion which to the normal person is red, appears black. The remainder of the red, the orange, the yellow, and the green appear as successively lighter shades of yellow which, toward the blue, becomes gray or white. This white shades into blue which deepens toward the violet end of the spectrum. In deuteranopia, which is the normal condition of a peripheral zone of the retina, the red of the spectrum is not shortened. Red, orange, yellow and green appear as lighter shades of one color, called red or yellow, and shade into a white or gray band which is a little nearer the red end of the spectrum than the corresponding band of protanopia. Blue is perceived normally. Tritanopia is a rare form in which yellow and blue are not recognized. The spectrum presents red and green portions, separated by a white band in place of the yellow. A dark green is seen in place of blue and the violet end of the spectrum is shortened.

Theories of Color Vision. Certain features of color blindness are ingeniously explained by Hering's theory, illustrated in figure 3. It is supposed that the cones contain a photo-chemical substance which is disassociated by red rays but which is built up by the green rays, giving rise respectively to the sensations of red and green. A second substance is broken down by yellow and built

up by blue light. As shown in the figure, orange is a mixed sensation due to the simultaneous partial destruction of the red-green and the yellow-blue substances. Yellowish green and greenish blue are likewise mixtures, and violet is supposed to combine the partial construction of the yellow-blue with the destruction of the red-green, the latter being indicated by the broken line. There are four pure sensations, red, yellow, green, and blue. Color blindness may be due to the absence or deficiency of the red-green substance (protanopia and deuteranopia, the two forms being varieties of a single type), or to lack of the yellow-blue substance (tritanopia). Hering further considered that there was a white-black substance, built up in darkness to give rise to the sensation

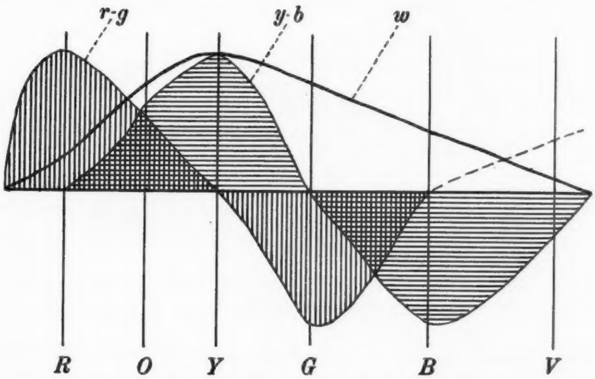

FIG. 3.— Diagram to illustrate Hering's theory of color vision. The red-green substance, *r-g*, is vertically shaded; and the yellow-blue substance, *y-b*, is transversely shaded.

of black, but destroyed in varying degree by different colored lights, thus giving white. In monochromatic vision the retina contains only this white-black substance. The curve *w* of figure 3 shows that the maximum stimulation of white is in the yellow portion of the spectrum. Without considering the difficulties concerning the white-black hypothesis, it may be questioned whether both constructive and destructive chemical processes can produce color sensations of similar nature. Mrs. Franklin considered that her theory was supported by the fact that the color sensations were all chemically destructive. Hering's theory, moreover, calls for four primary color sensations, whereas physi-

cists recognize that only three are necessary. Accordingly the physicist Young proposed a simpler theory antedating that of Hering. It was advocated by Helmholtz, and is generally known as the Young-Helmholtz theory.

According to the Young-Helmholtz theory there are three photochemical substances, red, green, and blue respectively, which are stimulated by the various rays of the spectrum as shown in figure 4. Absence of stimulation produces black, and the simultaneous disassociation of all three yields white. Protanopia is interpreted as red blindness, due to deficiency of the red perceiving substance. Deuteranopia is green blindness, and tritanopia is blue blindness. Since it would appear that the perception of white must be lost

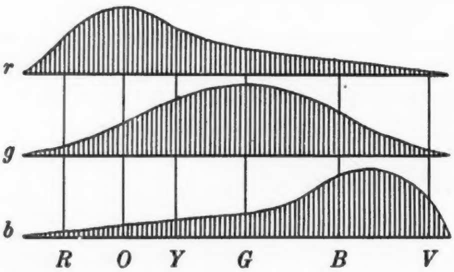

FIG. 4.— Diagram to illustrate the Young-Helmholtz theory. *r, g, b*, red, green, and blue perceiving substances, respectively.

with the disappearance of one of the three elements, the theory has been variously modified. In protanopia the red and the green substances may be so altered that each responds both to red and green light (Fick), or the red and the green substances may be imperfectly segregated, as assumed by Mrs. Franklin's theory. The close relation between the red and green substances is shown in Koenigs presentation of the Young-Helmholtz theory (Fig. 5). The absence of either would give rise to somewhat similar conditions, such as occur in protanopia and deuteranopia. The figure indicates that in trichromatic vision, the colors from yellow to blue affect all three substances to a certain extent, thus adding a small amount of white to the color sensation. In dichromatic vision the mixing of the two elements yields white. In case the red substance is absent, this white will appear nearer the blue than in case the green is absent; its position is indicated by the

intersection of the blue with the green and red curves respectively. In the absence of the blue substance, the white band is near the yellow. This accords with the observations upon the color blind. The absence of the green substance would not shorten the spectrum, but the lack of the red or blue would cut off their respective ends. All of these features are equally well explained if, instead of the absence of one of the three substances, such a modification of its reaction is assumed as would be illustrated by a lateral shifting of its curve in the diagram. Thus in red blindness the red curve is shifted to cover more closely the territory of the green; in green blindness the green is shifted toward the red; and in blue blindness the blue and green curves are brought together. Thus

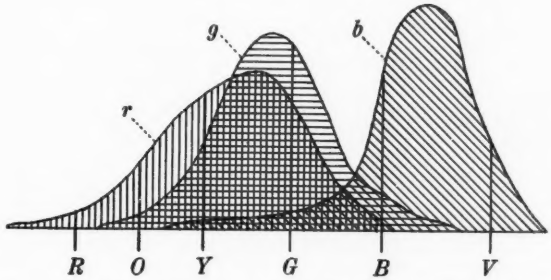

FIG. 5.— A modified diagram of the Young-Helmholtz theory, after Kœnig.

in the color blind all three substances are present but in modified form. Since this modified Young-Helmholtz theory accords so well with observations on color blindness, it is generally considered as the most satisfactory explanation of color vision.

An interesting attempt has been made by Patten to bring this theory into relation with structural elements in the cones.[1] He believes that the visual cells of invertebrates are characterized by a fibrillation which is transverse to the direction of the incident light waves, and that the tendency of the vertebrate rods and cones to separate into transverse discs is evidence of a similar structure. Many hundreds of such fibrils may exist in a rod or cone. They are not supposed to vibrate like tense strings, but

[1] Patten, W. A basis for a theory of color vision. *Am. Nat.*, 1898, vol. 32, p. 833–837.

to act as 'conductors or resonators,' a fact which would not exclude chemical changes resulting in fatigue. The long fibrils respond to the red end of the spectrum and the short ones to the blue. In rods the fibers are of equal length and only monochromatic vision is possible, but in the cones their varying length allows a range of color perception. Any variation in the form or dimensions of the cones would bring about corresponding changes in vision. The increased length of the cones at the fovea provides for a greater power of color discrimination. If the base of a cone were absent or cylindrical it would be red blind.

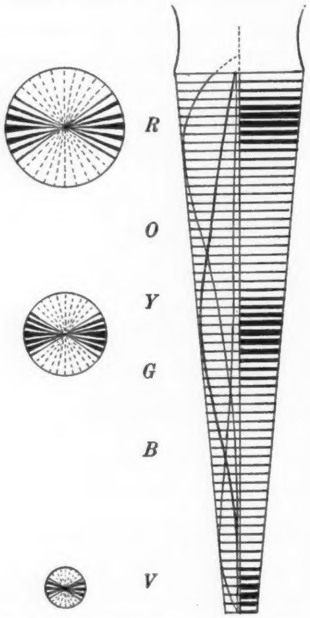

FIG. 6.— Diagram to illustrate the supposed fibrillar structure of human cones, and the way in which various light waves affect them. (Patten.)

This theory is illustrated in figure 6. On the right is the diagram of a cone and its fibrils; the latter radiate from an axial filament, the existence of which has been discussed and denied by other investigators. The fibrils in the right half of the cone are drawn as responding to red, yellowish green, and violet light; the Young-Helmholtz curves are shown on the left. In nonpolarized light all of the fibrils in a transverse section of a cone respond uniformly, but in polarized light only such are effected as are indicated in the cross sections on the left of the figure. Thus the dullness of polarized light is explained. The correctness of this supposition, as Dr. Patten states, will be determined by extensive measurements, much more accurate and detailed than any heretofore made, of the visual elements in all classes of animals.

It will be noted that according to Patten's and Mrs. Franklin's theories the mechanism for reaction to all the colors may exist in a single cone. The Hering theory calls for the reaction to at least

two colors in one cone; but according to the Young-Helmholtz theory, although the three substances could exist in a single cone, each is declared to exist in a cone by itself. This is considered to be strongly in favor of the validity of the Young-Helmholtz theory. Since physiologists find no instance in which different sorts of impulses are conveyed over a given nerve fiber, it is believed that a single cone fiber can transmit only one sort of color sensation. The stimuli of the red, green, and blue cones respectively are supposed to be gathered by separate nerve cells of the retina, and the optic nerve consequently contains certain fibers transmitting only red, green, and blue sensations respectively. The mixing of the sensations, giving rise to the perception of shades and tints, is therefore accomplished in the brain and not in the cones. In an attempt to test this supposition, attention has been called to the perception of the colors of stars. The image of the star is so minute that it would cover but a single cone, but the conclusion that one cone perceives its color is invalidated by the fact that the retina is not sufficiently stationary; the image of the star falls in rapid succession upon several cones which may unite in giving the color perception. Those who believe in the specific energy of the rod and cone fibers dismiss at once several of the theories of color vision. It must be remembered, however, that the separation of the cones into forms responding to red, blue, and green light, with three corresponding sets of nerve cells and fibers to convey these separate stimuli to the brain, does not rest upon anatomical evidence.

Physiological Laboratory
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THE BREEDING HABITS OF *AMBLYSTOMA PUNCTATUM* LINN[1]

BERTRAM G. SMITH

On April 9, 1906, in some small ponds in a wood in the vicinity of Ann Arbor, Michigan, Prof. Jacob Reighard discovered what he surmised to be spermatophores of Amblystoma. At his suggestion and under his direction, I undertook the identification and study of these structures.

I. Observations

A. **The Spermatophores.** The spermatophores look like bunches or tufts of snowy-white fungus growing on leaves, twigs, or stalks of grass lying on the bottom of the pond. They invariably occur on a horizontal surface, and are never attached to an erect twig or stalk as is often the case with the eggs of Amblystoma. They are found in water from 6 to 10 inches deep, and 5 to 10 feet from the shore. The spermatophores usually occur in groups of about 40 or 50, but the number is extremely variable, ranging from 1 to 100. Isolated spermatophores are rarely found, though a single one is conspicuous enough to be readily discovered. The spermatophores of each group are scattered over an area of rather more than one square foot. Along the shores of an elliptical pond about 125 feet in length, 25 groups of spermatophores were counted; they were less numerous in three other ponds examined.

The spermatophores (Fig. 1.) resemble those of *Triton* (*Diemyctylus*) *viridescens* as described by Jordan ('91 and '93) rather than the more complicated structures produced by some European forms (Zeller, '05). Each consists of a base and a stalk of clear gelatinous material almost invisible in the water, having the general form of the stump of a tree, this structure is surmounted by a slightly broader cap or tuft of snowy-white felt-like material consisting of spermatozoa with no visible matrix. The material con-

[1] Contributions from the Zoological Laboratory of the University of Michigan, No.

stituting the base must be strongly adhesive when fresh, for the spermatophore is firmly attached to the object on which it is deposited. The cap is usually hemispherical in form, with the convex surface upward; but the material of which it consists often runs down the side of the stalk, or is found projecting in downy tufts like the cotton from an open cotton-boll. In many cases the caps have a frayed appearance, as if they had been disturbed; in occasional specimens the cap of spermatozoa is partly or almost wholly absent. The appearance in the latter case is like that of a spermatophore of *Triton viridescens* from which I have seen the ball of spermatozoa taken up into the cloaca of a female. The dimensions of the complete spermatophore are about as follows:

Height	6–8 mm.
Breadth of base	6–8 mm.
Diameter of stalk near top	2.5–3 mm.
" " cap	3–4 mm.

As compared with some spermatophores of *Triton viridescens* obtained from specimens in captivity, these under discussion are slightly taller, with a smaller base and a stalk of much larger diameter, surmounted by a larger mass of spermatozoa. The spermatophore of *Triton viridescens* has a broad flattened base from the center of which rises a distinctly conical stalk tapering to a very slender spine, at the top of which is attached a small ball of spermatozoa; the spermatophores attributed to Amblystoma are more massive and more nearly cylindrical.

When found on April 9 and 10 the spermatophores were all in good condition, with some slight differences in the freshness of their appearance. In two or three days they became infested with fungus, disintegrated quite rapidly, and in a week very few few of them could be found. Had new ones been deposited in the interval, they could readily have been distinguished from the old ones; but no more spermatophores were deposited. Hence it is scarcely possible that the period during which spermatophores are deposited lasts longer than two or three days.

The spermatophores shown in the figure had been attacked by fungus and were beginning to disintegrate when photographed. The base is therefore no longer clear, but on the contrary the whole spermatophore appears white.

Identification. In order to identify the spermatophores, search was made for the parent animals. This resulted in the capture on April 11, of three specimens of *Amblystoma punctatum* Linn. which were found embedded in rotten wood under a stump at the edge of the water of one of the ponds where the spermatophores were numerous. From two of these specimens a few drops of seminal fluid, containing an abundance of spermatozoa, were obtained by stripping; from the third, which proved to be a female,

FIG. 1.— Spermatophores of *Amblystoma punctatum*. Two-thirds natural size, linear reduction.

comparatively few spermatozoa were obtained. The spermatozoa were mounted, stained, and compared with some taken from spermatophores and similarly treated. In structure, size, and staining reactions the two were identical.

Another species, *A. tigrinum* Green, also occurs in the vicinity

of Ann Arbor, and a single example was taken on April 9, in a field several hundred yards distant from the nearest pond where spermatophores were found; but the eggs of the two species are easily distinguishable, and in the case of *A. punctatum* were identified by means of eggs laid in the laboratory. With the exception of one bunch of eggs of *A. tigrinum,* all the eggs found in the pond where spermatophores were observed, were those of *A. punctatum.* With the single exception above noted, the two species have not been known to breed in the same ponds in the vicinity of Ann Arbor.

B. **The Spermatozoa.** The spermatozoon of *Amblystoma punctatum* is extremely long and slender. The head stains well with Delafields' haemotoxylin, the middle-piece less deeply. The tail-piece is bordered on one side by a very delicate undulating membrane. Some of the dimensions are as follows:

Length of acrosome	20 μ
" " head	106 μ
" " middle-piece	14 μ
" " tail-piece	480 μ
Total length	620 μ

The spermatozoon resembles in size and form that of *Triton viridescens,* with which it was compared, but the latter has a middle-piece twice as long, and a more conspicuous undulating membrane.

As compared with the spermatozoon of *Crytobranchus allegheniensis* (Smith '06) the sperm of *Amblystoma punctatum* is nearly three times as long, with a proportionally much longer middle-piece; the entire structure is much more slender and thread-like.

In freshly mounted seminal fluid the spermatozoa were seen in active motion. They tend to cling together parallel to each other to form bundles or ringlets, revolving with a circular motion; when so clustered they retain their vitality much longer than when separated. In a dying spermatozoon, long after the shaft has ceased to move, the activity of the undulating membrane continues. It gradually becomes slower until with a high magnification it is possible to follow a trough or a crest without interruption or change of form across the entire field of the microscope. The undulating membrane does not wind about the shaft as in Cryptobranchus, but continues on one side of it. When dead, the sperms are usually

found much convoluted, indicating a greater degree of flexibility than is the case with stouter spermatozoa like those of Cryptobranchus.

Experiments were performed to determine the length of time the spermatophores would retain their vitality in water, hence the interval within which they would have to be taken up by the female. In all the spermatophores examined the spermatozoa were motionless; but since the examination was not made until the evening of April 10, probably the spermatophores had been in the water for many hours. The effect of the cloacal secretion of the living female was then tried, to see if it would revive these spermatozoa; no such result was produced. Freshly obtained seminal fluid mounted in water retained its vitality for many hours; but as this experiment was not performed until April 18, only a small amount of seminal fluid could be obtained, and in this the sperms were not in a vigorous condition. If fresh seminal fluid were taken in the proper season and mounted in quantities to correspond with that deposited in a spermatophore, it might retain its vitality much longer. The viscous liquid in which the spermatozoa occur does not readily mix with water.

A freshly deposited spermatophore of *Triton viridescens* was obtained and kept in water; from time to time small portions of the ball of spermatozoa were teased apart and examined under the microscope. Eleven hours from the time the spermatophore was deposited, many active spermatozoa were found; an hour later all were motionless. Probably in an undisturbed spermatophore their vitality would be retained longer than twelve hours.

C. **The Eggs**. Those of *A. punctatum* have been described and figured by Clark ('80). The eggs, with their individual gelatinous envelopes, occur in compact bunches, surrounded by a very thick jelly mass. The entire structure is usually of an oval shape, often nearly as large as one's fist. The eggs of *A. tigrinum* are more loosely aggregated in a thinner jelly mass, and the cluster resembles a bunch of grapes. The clusters of eggs of *A. punctatum* are as a rule larger than those of *A. tigrinum*, and the number of eggs in a bunch is usually greater.

At the time of the discovery of the spermatophores, very few bunches of eggs could be found. The number steadily increased for a week; at the end of that time eggs were found in early seg-

mentation stages, showing that they had been quite recently laid. The egg-laying season follows immediately after the deposition of spermatophores, and lasts six or seven days. Nearly every bunch of eggs found on April 10 was close to a group of spermatophores.

On April 16, in the pond where 25 groups of spermatophores had been counted nearly a week before, about 55 bunches of eggs were found. Of these, many bunches were deposited in groups of two to four, probably by the same female. The number of aggregations of eggs very nearly equalled the number of groups of spermatophores.

D. **The Adults.** *Secondary Sexual Characteristics.* During the breeding season, at least, the cloacal region of the male is quite prominent; that of the single female examined was much less swollen, and the orifice was smaller. The cloaca of the male is lined with fine parallel papillated ridges, extending inward for a few millimeters; between these ridges are deep grooves, lined with cilia whose beat is outward. These ridges and grooves were not found in the single female examined. According to Kingsbury ('95) the female Amblystoma, as well as the male, has cilia in the cloaca but the tract is less extensive. The urogenital sinus of the male is larger than that of the female, probably to hold a considerable supply of seminal fluid preliminary to the deposition of a spermatophore. No secondary sexual characters to indicate the clasping of the female by the male were found.

II. Discussion.

Andrews ('97) described the structure and distribution of some spermatophores which he attributed to *Amblystoma punctatum,* but without positive identification. He states that these spermatophores were more slender and higher than those of *Triton viridescens,* and were distributed, at intervals of a few inches, in lines of several to a dozen. I find it difficult to reconcile his account with my own observations.[1]

[1] Professor Andrews, to whom the manuscript of this paper was submitted, writes,—"The spermatophores vary in size, arrangement and form here (about Baltimore) in different years and ponds; and I think your comparison with a tree stump a good one to indicate their common form. I judge the discrepancy in our account to be one of words rather than of observations. I am convinced from your photograph and account that you have described the same spermatophores that I did, and I judge both observations — despite some differences in descriptions — refer to Amblystoma punctatum."

On account of the late season at which my investigation was begun, no direct observations of the process of fertilization were possible. Clark ('79) says of some specimens of *A. punctatum* in confinement: "The males showed no inclination to clasp the females, but quietly deposited quite large masses of an apparently rather thick liquid, opaque white, on the bottom of the dish in which they were kept. Upon examination this was found to consist of spermatozoa moving actively in a liquid." The manner in which the spermatozoa reached the eggs was not observed.

Fertilization is undoubtedly internal. Of this the evidence adduced by Kingsbury ('95), and the presence of spermatozoa in the cloaca of the female as described above, furnish sufficient proof. It remains to consider how the transfer of spermatozoa is effected by the spermatophores.

The number of spermatophores is evidently very much greater than the number of females; and unless there exists an enormous disproportion between the sexes, each male must deposit a large number of spermatophores. Their abundance and the manner of their distribution, render it a very easy matter for the female to find enough of them for purposes of fertilization. In some portions of the pond it would seem scarcely possible for a female to move about in the water for any length of time without brushing against some of these spermatophores; hence there is the possibility of finding them by chance contact.

In the cases of those Urodela in which, as in *Triton viridescens* (Jordan '91 and '93; Hilton '02) and Axolotl (Gasco '81) the number of spermatophores deposited by a single male is small, particular safeguards are needed in order to facilitate their delivery to the cloaca of the female. In these forms the physiological necessity which requires the co-operation of the female in order that spermatophores may be deposited insures the presence of the female at the right time; subsequent reactions safeguard the reception of at least one of these spermatophores by the female cloaca. In *Triton viridescens*, according to my own observations, in some cases the female seems to make a definite attempt to get the spermatophore. The complicated behavior of the adults in these cases finds its biological significance not only in the increasing certainty of the process, but in a corresponding economy in the

number of spermatophores that must be deposited. With *Amblystoma punctatum*, on account of the very large number of spermatophores, there is the probability of a simpler mode of behavior, and the spermatophores may be found largely by chance. The wastefulness of the method is obvious. In Amblystoma as in Axolotl there is evidently no clasping of the female by the male, such as occurs in Triton.

The result of the experimental work on the vitality of the seminal fluid in water indicates that the spermatophore is not necessarily taken up by the female immediately after it is deposited; probably it is capable of effecting fertilization after exposure to the water for many hours.

On account of the shortness of the breeding season, the spermatozoa can be retained in the cloaca of the female for only a few days at most, before fertilization is effected. The position with respect to the spermatophores, of the earlier eggs found, suggests that in some cases the eggs are deposited immediately after the spermatophores are picked up.

The extreme flexibility of the sperm is doubtless correlated with the process of internal fertilization. In Cryptobranchus, in which fertilization is external (Smith '07), the egg envelopes must be penetrated after a brief exposure to the hardening effect of the water, and a much more rigid spermatozoon is required.

In the evolution of terrestrial from aquatic vertebrate life, a transition from external to internal fertilization takes place. External fertilization is not adapted to terrestrial conditions, hence in the land-living vertebrates it occurs only in some of the forms that revert to the water during the breeding season — *i. e.* in the Amphibia. Internal fertilization is an adaptation to terrestrial life in the sense that it is a condition antecedent to that life, not a result brought about by it; it may occur in purely aquatic vertebrates, as in the Elasmobranchs and a few Teleosts. Internal fertilization by means of spermatophores is a method still adapted to aquatic rather than to terrestrial conditions. It is a method intermediate between external fertilization on the one hand and internal fertilization without spermatophores on the other. Viewed in the light of the habits of the higher vertebrates, the occurrence of any method of internal fertilization in a form that breeds in the

water represents an advance upon the habit of external fertilization, and a stage in the evolution of habits that are to make possible the invasion and permanent occupation of the land.

Internal fertilization also finds a biological significance in the fact that in the course of its development there is gradually effected an economy in the amount of seminal fluid required for fertilization. This factor may account for the persistent development of the habit under aquatic conditions, where external fertilization is still possible; the incidental result is a preparation for terrestrial life.

In existing Amphibia we may find illustrations of various stages in this evolution of the breeding habits correlated with a transition from the water to the land. In Cryptobranchus, one of the lowest of the Urodela, leading an aquatic life and showing only in its methods of respiration and locomotion an advance toward terrestrial conditions, external fertilization takes place. This is evidently the primitive condition for the Urodela. In Amblystoma, a urodele living partly upon the land but returning to the water to breed, we see developed the peculiar habit of fertilization by means of spermatophores — a mode of internal fertilization favored by aquatic conditions. In *Triton viridescens* an economy of seminal fluid through a reduction in the number of spermatophores is made possible by definite reactions on the part of the adults, which insure fertilization. In the urodeles *Megapterna montana* Savi., *Molge aspera* Dugès and *Glossoliga Hagenmulleri* Lataste, according to Bedriaga ('82 and '95) the male emits spermatophores while still clasping the female; in *Triton torosus* Esch. (Ritter '99) it is probable that a very similar process occurs; in none of these cases, with the possible exception of *Molge aspera,* is there direct cloacal contact. Finally in the Apoda (the Sarasins '87–'93; Brauer '97) we find the establishment of a method of internal fertilization by direct cloacal contact, thus fulfilling the requirements for continuous residence upon the land.

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THE STAFF-TREE, *CELASTRUS SCANDENS*, AS A FORMER FOOD SUPPLY OF STARVING INDIANS

FRANK T. DILLINGHAM

In many kinds of hard and horny seeds there is present, as a reserve material, a carbohydrate which upon hydrolysis yields *mannose* (a simple sugar closely related to glucose). This carbohydrate has been named *mannan.* It is one of the hemi-celluloses, a group of substances closely resembling in appearance the true celluloses, but easily resolved into simpler carbohydrates by the hydrolytic action of enzymes or of dilute acids. There is no lack of evidence that mannan which occurs abundantly in the so-called vegetable ivory, *Phytelephas macrocarpa,* and in the seeds of many other palms, as well as in the wood of coniferous trees, is in spite of its hardness, fit food for camels, neat cattle, sheep, and various rodents. This is illustrated in the girdling of pine trees by mice, as recorded by Thoreau in "Walden."[1] He says:— "There were scores of pitch-pines around my house, from one to four inches in diameter, which had been gnawed by mice the previous winter,— a Norwegian winter for them, for the snow lay long and deep, and they were obliged to mix a large proportion of pine bark with their other diet. These trees were alive and apparently flourishing at mid-summer, and many of them had grown a foot, though completely girdled; but after another winter such were without exception dead. It is remarkable that a single mouse should thus be allowed a whole pine tree for its dinner, gnawing round instead of up and down it; but perhaps it is necessary in order to thin these trees, which are wont to grow up densely."

It is known that the root of a Japanese plant, *Conophallus konnjaku,* rich in mannan is used as human food, and the question may fairly be asked whether the former use of bark bread by the inhabitants of Scandinavia might not have been dependent upon the mannan in the bark. After discussing this matter in the

[1] Walden, p. 300. Jas. R. Osgood & Co. Boston, 1876.

Bulletin of the Bussey Institution (1906, Vol. 3, pp. 120–128), the writer learned that some tribes of North American Indians in times of extreme dearth were accustomed to keep body and soul together by boiling and eating the bark of the Staff-tree, *Celastrus scandens*. The Staff-tree is also called the staff-vine; false, climbing or shrubby bittersweet; wax-work, fever-twig, yellow-root, climbing orange-root and Jacob's ladder.

Radisson, wintering near the outlet of Lake Superior about the year 1658, found the Indians suffering greatly from starvation He writes:[1]— "Those that have any life seeketh out for roots, which could not be done without great difficulty, the earth being frozen 2 or 3 feet deep, and the snow 5 or 6 above it. The greatest subsistence that we can have is of rind tree which grows like ivy about the trees; but to swallow it, we cut the stick some 2 foot long, tying it in fagot, and boil it, and when it boils one hour or two the rind or skin comes off with ease, we take and dry it in the smoke and then reduce it into powder betwixt two grain stones, and putting the kettle with the same water upon the fire, we make it a kind of broth which nourishes us, but become thirstier and drier than the wood we ate."

In the Report of the U. S. Commissioner of Agriculture for 1870, (p. 422), there is the following statement:— "The Chippewa Indians use as food the tender branches of the Staff tree (*Celastrus scandens*). This climbing shrub, the *bois retors* of the French, or twisted wood, is sometimes called *bitter sweet*. It has a thick bark and is sweetish and palatable when boiled."

In view of the above statements, specimens of both the bark and the wood of the Staff-tree were tested for mannan. On the grounds of the Bussey Institution, on Jan. 24th, 1907, branches of the Staff-tree were cut in pieces about one foot in length. Both the inner and outer bark were removed together, no attempt being made to separate them. The outer bark was thin, but the inner bark was thick and fleshy. The material was carefully dried, ground to a fine meal, and a weighed quantity of it was boiled with dilute hydrochloric acid for three hours. A small portion of the liquor thus obtained was neutralized with sodium hydroxide and examined for mannose by the addition of a few

[1] Voyages of P. E. Radisson, p. 204, Prince Society Edition, Boston, 1885.

drops of phenylhydrazine acetate. No mannose hydrazone crystals formed at this point. The remainder of the liquor, after being similarly neutralized, was evaporated to dryness; the residue was treated with a small quantity of water; and the concentrated liquor thus obtained was tested for mannose by adding a few drops of phenylhydrazine acetate. With the aid of the microscope, the formation of characteristic crystals of mannose hydrazone was observed.[1] The wood proper (including the pith) was reduced to a fine meal and then treated in precisely the same manner as was the bark.

From these tests it appears that unlike the bark of most deciduous trees, that of the Staff-tree contains an abundance of mannan. The bark of the Staff-tree, moreover, contains a larger quantity of mannan than does the wood proper.

To confirm Radisson's statement as to the effect of boiling, a few branches of the Staff-tree were boiled with water for about one hour. At the end of this time the bark was found to peel off with great ease. It was seen to be thick, pulpy, and very mucilaginous, and it had a rather agreeable taste.

It is evident from these experiments that a part, at least, of the physiological value of the bark of the Staff-tree may be justly attributed to the presence of mannan.

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[1] This method has been explained in detail in the Bulletin of the Bussey Institution. 1902, 3, p. 30. 1903, 3, p. 47.

NOTES AND LITERATURE

GENERAL BIOLOGY

The Spirit of Nature Study.[1]— Nature may be approached in a very unscientific spirit. Thus Emerson was led to dedicate to the *Botanist* the following quatrain:

> Go thou to thy learned task,
> I stay with the flowers of Spring:
> Do thou of the Ages ask
> What me the Hours will bring.

What the hours brought he so expressed that the Rhodora has become a universal type of botanic beauty. In a different spirit the New England botanists named their journal *Rhodora*, for they profess to have been uninfluenced by Emerson's familiar lines; they sought a characteristic local plant with a short name which would commend itself to bibliographers. The spirit of nature study, according to Dr. Bigelow's interpretation, combines the sentimental and the scientific, with its emphasis upon the former. This appears in such advice as,—"Take frequent rambles into the country; associate with natural objects, love them, take them into your nature, and treasure the remembrances of them.... Subsequent years of trouble cannot obliterate the charmed impressions." "At the next stopping place there will be no fairer landscapes, nor more beautiful skies, no statelier trees, more joyous songsters, nor brighter flowers; more cheerful hum of insects, more invigorating air, no more happiness, no better friends, and no better God."

Therefore more time should be given to nature study in the schools, and many educators are quoted to this effect. School children should be taken to the country and should have plants and animals at home; rabbits and gourds are particularly recommended since the former are reasonably small and the latter grow upward 'where land is cheap.' College methods of instruction should not be extended to elementary schools. Of the sixteen half-tones which illustrate the book, twelve are photographs of boys and girls out in the country.

The nature student, as Burroughs has said, does not regard birds

[1] Bigelow, Edward F., *The spirit of nature study.* New York, A. S. Barnes & Company, 1907. 12mo, 222 pp.

as ornithological specimens, nor wild flowers as material for herbaria. Dr. Bigelow's expeditions are not for 'what one can get.' It is apparent that within the present century the destruction of such irreplacable plants and animals as remain will not be tolerated, either for sport, for food, or for amateur collections. Since nature study in the schools should save the swallows' banks from the small boy and proteot native plants from bouquet gatherers, it may prove of great value to the community. This, however, is not strongly presented in Dr. Bigelow's book, which includes a photograph of eleven women gathering bunches of violets, and recounts, as one of the author's pleasurable reminiscences, the bloody death of a woodchuck.

Dr. Bigelow's twenty-three informal essays are enlivened by many quotations and anecdotes; their author appreciates the "fun of being a naturalist" and his good natured humor is all at the expense of the "bug-hunter's" critics. He is at home with boys and girls for whom he edits each month an excellent department of Nature and Science in *St. Nicholas,* but the book here considered is addressed to parents and to teachers of nature study.

Heterogenesis.— The idea that eggs of one species may give rise to adults of other species still finds an occasional advocate undismayed by overwhelming evidence to the contrary. A contribution recently submitted to the *Naturalist* set forth breeding experiments in which several species of insects hatched from a single batch of eggs, and none were parasites. The suggestion of a distinguished entomologist that in these days of the multiplicity of species, several might readily arise from one lot of eggs, was here inapplicable, for different genera were involved. The probable explanation is that the technique of the experiments was faulty. Dr. H. Carlton Bastian continues to believe in heterogenesis, upon which he has published voluminously, but a skeptical critic of his latest book concludes with the following anecdote.[1] "On one occasion, Dr. John Rennie, lecturer on parasitology in the University of Aberdeen and an expert investigator, observed two infusorians moving inside a rotifer's egg, but he did not regard the phenomenon as a proof of heterogenesis. As a matter of fact the egg envelope showed a small split through which the infusorians soon passed out, doubtless following the path by which they formerly entered."

F. T. L.

[1] Bastian, H. C. *The evolution of life.* Reviewed in *Nature,* May 2, 1907, vol. 76, p. 1.

ZOOLOGY

Anatomical Terminology.[1] — In descriptive anatomy, as in systematic zoology, synonymy has been a heavy burden. In a current text book a paragraph of five lines begins with "*The Corium, Cutis vera, Dermis,* or *True Skin*"; and another, which is not exceptional, announces "*The Simple Follicles, Intestinal Glands, Crypts,* or *Glands of Lieberkühn, glandulæ intestinales* [*Lieberkuehni*]." In America since 1871, Professor Burt G. Wilder has been active in reform with the following results. In 1889 the Association of American Anatomists voted to employ the adjectives *anterior, posterior, dorsal* and *ventral,* in the sense of toward the head, tail, back, and abdomen respectively. They substituted *thoracic vertebra* for dorsal vertebra, and approved the terms *calcar, hippocampus, pons, insula, pia,* and *dura.* In 1896 the Neurological Association adopted forty terms pertaining to the nervous system. The Association for the Advancement of Science went so far as to sanction the most unfortunate principle of Professor Wilder's system, namely that terms should be single words rather than descriptive phrases. This principle leads (1) to the introduction of shorter new names to replace more familiar older ones; (2) to the omission of nouns, making the descriptive adjective the complete term; and (3) to the fusion of two words in one, often combined with the elimination of certain syllables. The omission of *mater* from dura mater, and of *tunica* from tunica muscularis is common and desirable in the laboratory, but the noun is understood and is an essential portion of the name. Nothing is gained by ruling it out of existence. The following are examples of fused words,— *transection* for transverse section; *postcava* for vena cava posterior; *alinjected* for injected with alcohol; *terma* for lamina terminalis. In this system the elimination of synonyms becomes secondary to a kind of anatomical spelling reform.

In 1889 the Anatomische Gesellschaft appointed a committee of nine eminent anatomists to revise anatomical nomenclature, and after six years' labor it reported a list of about forty-five hundred Latin terms. An even larger number of synonyms was rejected. Unfortunately *anterior* is used as equivalent to *ventral, superior* is some-

[1] Barker, Lewellys F., *Anatomical terminology.* Philadelphia, P. Blakiston's Son & Co., 1907. 8vo, ix + 103 pp., 5 figs.

times employed for *anterior*, and in some other instances, as in naming the dorsal pancreas *accessory pancreas*, the bias of human anatomy is apparent. In this respect Professor Wilder's rejected principle ought not to be abandoned. The German committee has adopted thirty-four of the forty terms sanctioned by the American Neurological Association; in ten of these, however, nouns which had been dropped as superfluous are retained. In general, the committee declined to introduce new terms, to combine nouns and adjectives, or to eliminate syllables or letters for brevity. It followed Professor Wilder's advice in preferring descriptive to personal names, definitely retaining only two of the latter, *Wolffian* and *Muellerian*. Intestinal glands, parotid duct, splenic nodule, and renal corpuscle replace glands of Lieberkuehn, Stenson's duct, and Malpighian corpuscle, the last term having been applied to radically different parts of the spleen and kidney.

After a trial of more than ten years this anatomical nomenclature adopted at Basle, and known consequently as the BNA, has become the standard terminology. The writer has found it necessary to have the report of the German committee always at hand. This report has been made easily available by Professor Barker of Johns Hopkins University. In a preface of twelve pages he describes the origin of the Basle nomenclature. On the left hand pages of his book are the Latin terms in two columns, reprinted in full and without modification from the German report. On the right hand pages there are two corresponding columns of English translations of the terms, together with some of the current rejected names. He says, on page 1, "The English vocabulary is simply explanatory; in many instances it would be unwise to use the English synonyms given, and in many more instances anatomists would differ as to the most suitable English equivalent to be chosen. Each anatomist is of course at liberty to use whatever English equivalent he desires for the official Latin terms. Students are strongly advised, however, to use the original Latin terms as English words. The Latin terms are the only authorized ones." We agree with Professor Barker that "the sooner a general decision to adopt these terms is reached, the better it will be of anatomical instruction and research, and the easier it will be for teacher and taught."

F. T. L.

The Blending and Overlap of Instincts in Birds.[1] — Wild birds are described as passing annually through a cycle of instinctive activities

[1] Herrick, F. H. Analysis of the cyclical instincts of birds.— The blending and overlap of inst'ncts. *Journ. of Comp. Neur.*, 1907, vol. 17, pp. 194–197.

including (1) spring migration; (2) courtship and mating; (3) nest building; (4) egg laying and incubation; (5) care of young; and (6) fall migration. Some birds, like the robin and blue bird, pass through two or three reproductive cycles before the fall migration. The fish hawks and eagles which repair their old nests in the autumn do not act in "anticipation of spring" but exhibit a recurrence of the nesting instinct, due to beginning a new cycle which is never finished. Young birds may be abandoned in the fall when the migratory impulse overlaps the parental instinct. "An adult robin has been seen to offer a string to its fully grown young, and try to cram it down the throat of a fledgling. Later the old bird flew with the string into a tree. This was the result of the overlapping of two reproductive cycles. The bird was alternately swayed by opposing impulses, now being impelled to gather nesting material when she picked up the string, now by parental instinct to feed her young when she tried to serve it, and again possibly by the instinct of building when she flew with the string into a tree."

When a vireo's nest contains a cowbird's egg and a new story is added to the nest by the vireo, it is not for the purpose of eliminating the cowbird's egg, which it does so perfectly. It indicates rather that the reproductive cycle has been broken by fear, and a new one is begun, in these rare cases the old nest being retained as a site to build upon. The herring gull also will bury its eggs when its cycle has been interrupted through fear.

This interesting interpretation of anomalous actions in birds is followed in the Journal of Comparative Neurology by an extraordinary explanation of the brooding habit of the male salamander, *Cryptobranchus alleghеniensis*.[1] It states that "after the eggs are deposited they are usually guarded for a time by the male, who fights and drives away other hellbenders which attempt to eat the eggs. The male himself eats some of the eggs, but on account of the slowness of his digestion is unable to eat more than a small proportion, hence his presence is in the main protective. In defending the eggs the male is only guarding his own food supply: the origin of the brooding habit in this case seems to be the feeding habit." If one doubts that the perpetuation of this species depends upon a providential slowness of digestion, a blending of the feeding and brooding instincts may be substituted.

F. T. L.

[1] Smith, B. G. The habits and life history of *Cryptobranchus allegheniensis*. *Journ. of Comp. Neur.*, 1907, vol. 27, pp. 197–198.

A Preliminary Note on the Variation of Scutellation in the Garter Snakes.— Three years ago the writer began an investigation into the relationships of the different races of garter snakes (Thannophis) in an attempt to determine the laws involved in the differentiation of the genus. The results of this work are being included in a monograph of the genus, but as it will be several months before this work can be completed it has been thought best to publish a brief outline of some of the conclusions.

In the progress of this investigation it was seen very early that before a serious attempt could be made to determine the affinities of the different races, the significance of the variations in scale arrangement or scutellation must be determined. This was attempted with the following results:

(1) The number of dorsal scale rows on an individual snake decreases posteriorly by the elimination of certain rows, and the series eliminated are always the same for snakes with the same number of rows, as for example *T. sirtalis* and *T. saurita.*

(2) The rows dropped posteriorly in individual snakes are those which have entirely disappeared in races with a fewer number of scale rows.

(3) The reduction in the number of dorsal scale rows is generally accompanied by a reduction in the number of labial, ventral, and subcaudal scales (gastrosteges and urosteges).

(4) There is considerable evidence that the reduction in scutellation is directly or indirectly associated with a diminution in size.

The general reduction in scutellation described above is exhibited by each of the several (natural?) groups into which the genus can be divided. These groups all occur together only in northern Mexico, which may be considered the center of origin for the genus. The races that occur in this region all exhibit the maximum scutellation for their respective groups, the dwarfing in size and scutellation taking place at points away from the center of origin. The discovery of these methods of variation in the different series of scales has been an indispensable aid in determining the affinities of the different races.

Alexander G. Ruthven

A Simple Method for removing the Gelatinous Coats of Eggs.— In the course of work in which it was necessary to handle a number of amphibian eggs the writer hit upon a simple and rapid method of freeing them from their gelatinous envelopes. While, because of its

very simplicity, it seems impossible that other workers have not used the method, still the writer has been able to find no reference to it in embryological literature and he records it here, therefore, because he feels that it will be very serviceable to workers who have to handle such material.

The method consists simply in placing the egg on a bit of blotting paper and then rolling it over and over, thus reversing the small boy's method of rolling up a large snow ball. Either fresh or preserved eggs may in this way be rapidly removed from their envelopes and transferred by means of a spear-headed needle or a paper spatula to the fixing reagent. The method worked well on frog and salamander eggs that had been preserved in formalin for two years, and on millipede eggs which had been similarly preserved for over three years.

When using the method with certain kinds of fresh material, the eggs may be so soft that when finally unrolled from their coats they are drawn down so as to adhere tightly to the blotting paper. To avoid this, (1) roll them off onto a paper of harder texture just before the last trace of gelatinous film has been removed from their surfaces, or (2) first fix them (*e. g.*, in Gilson's mercuro-nitric mixture) and then, before further hardening in alcohol, roll them out of their envelopes on the blotter.

MICHAEL F. GUYER

The Star-nosed Mole on Long Island, N. Y.— In a recent (1902) list of the mammals of Long Island, Arthur H. Helme states that the only evidence of the presence of the star-nosed mole (*Condylura cristata*) on the island that has come to his knowledge is the finding of a single dead specimen. It seems then worth recording that on April 18 a star-nosed mole, which had been caught by a cat, was sent me from Great Neck, Long Island, by Miss Elise Gignoux.

JOHN TREADWELL NICHOLS

Notes.— Under the name *Cirrodrilus cirratus* U. Pierantoni has described[1] a peculiar-looking worm, about 3 mm. long, found as a parasite on the crayfish of Japan. It is cylindrical, and consists of a large head and following this eight body segments, the anterior six having short fleshy finger-like processes arranged in a transverse line on the ventral surface. The mouth is nearly surrounded by a ring of similar longer processes, whence the name cirratus. The mouth is armed with a pair of horny jaws like those of certain Branchiob-

[1] Bolletino Societià di Naturalisti in Napoli, 19, 1905.

dellids with which group (or the Histriodrilids) the author is inclined to place it. The internal structure was not studied.

The Systematic Position of Trichoplax. Ever since its discovery Trichoplax has been one of the zoological problems, and now Thilo Krumbach of Breslau offers evidence[1] to show that it may be the planula of the hydroid Eleutheria. His proof is not conclusive but is based upon the histological similarities between the planula and Trichoplax, and upon the fact that Trichoplax appeared suddenly in great numbers in a tank where the nudusa *Eleutheria krohni* occurred. He suggests also that Monticellis *Treptoplax reptans* belongs to *Eleutheria claparedi.*

Caesar Böttger reports[2] *Petricola pholadiformis* from the North Frisian Islands, and quotes also its presence from the East Frisian Islands. It has previously only been known from the Atlantic coast of America. It is now distributed over quite a territory and the problem is how and when did it reach the old world?

Kofoid points out[3] that the genus Polykrikos which occurs abundantly at San Diego, California, is really a colonial infusorian consisting of two, four or rarely eight zooids and that its place is in the family Gymnodinidæ of the Dinoflagellates. Apparently the same species, *Polykrikos schwartzi* occurs on the Californian and European coasts. *P. auricularia* of Bergh is regarded as a synonym.

Haswell[4] repeats his observation of Euglena-like organisms as intracellular parasites in rhabdocoele turbellarian worms.

The Museum at Bergen, Norway, has begun the publication of a series of monographs dealing with the marine fauna of the vicinity. The second and third *Hefte* issued last year, but only now received, deal with the Bryozoa by O. Nordgaard and the Decapod Crustacea by A. Appellöf.

J. S. KINGSLEY.

[1] Zool. Anzeiger, 31, p. 450, 1907.
[2] Zool. Anzeiger, 31, p. 268, 1907.
[3] Zool. Anzeiger, 31, p. 291, 1907.
[4] Zool. Anzeiger, 31, p. 296, 1907.

BOTANY

Cytology and Mutation.— Immediately after the rediscovery of Mendel's law and the publication of DeVries's great work on mutation, cytologists began seeking for some basis for these phenomena in the organization of the germ cells. The most recent contribution to the literature of this subject is a paper by Gates[1] on *Œnothera Lamarckiana* and *O. lata*.

The author finds that the regular abortion of the pollen in *Œnothera lata* is not due to the filling of the anther cavity or loculus by an ingrowth of its lining (the tapetum) as described by Pohl, but to some other agency the nature of which is not yet explained. Pollen development may proceed to the formation of the tetrads, but degeneration of both the mother cells and the tapetum frequently begins in the resting stage or in the prophase of the first mitosis. If the tapetal cells always degenerated before the pollen mother cells, we might conclude that the failure of the former to secrete nutriment for the pollen was the immediate cause of sterility. But this is not always the case for the degeneration of the pollen mother cells may precede that of the tapetum. The writer is inclined to accept the hypothesis that the maternal and the paternal chromatin remain separate in the somatic cells, and also in the germ cells until maturation approaches. Then the intimate union which occurs during synapsis may lead to incompatibilities between the plasms and to the more or less complete failure of further development.

A second point of interest is the demonstration of peculiar chromosomes, called "heterochromosomes." They arise in *O. lata* in the prophase after synapsis by the cutting off of a portion or loop of the spireme thread before the remainder breaks up into chromosomes. A cell may contain one or two of these bodies which appear as large rings, usually seen in the cytoplasm near the spindle. They do not divide but become smaller and probably disappear at the end of the first mitosis. In the *O. Lamarckiana* hybrid these bodies also occur. The author thinks that they represent discarded chromosomes and are, perhaps, a means of lessening the number of chromosomes in certain

[1] Gates, R. R. Pollen development in hybrids of *Œnothera lata* × *O. Lamarckiana*, and its relation to mutation. *Bot. Gaz.*, 1907, vol. 43, pp. 81–115, pl. 2–4.

germ cells. Some mother cells do not contain them, but it could not be demonstrated that these have fewer ordinary chromosomes than the others. The number of chromosomes in *O. lata* is fourteen; in the hybrid with *O. Lamarckiana* it is "probably twenty"; and in pure *O. Lamarckiana* the number, as yet undetermined, is thought to vary. Since a different number of chromosomes in closely related species has apparently never before been recorded, these observations if they are verified by further investigations are of great interest. The author dismisses the idea that *O. Lamarckiana* is itself a hybrid, but this also is an important subject for further study. He concludes that the mutations of *O. Lamarckiana* probably arise during the reduction divisions, and that the pollen grains which give rise to mutants may differ in their chromatin morphology from the ordinary pollen of the plant.

J. A. Harris

Variation and Differentiation.— Dr. Pearl has recently published an exhaustive study of the intra-individual variation and differentiation in Ceratophyllum.[1] The purpose of the author was "to work out as exactly and completely as possible for a particular organism the laws according to which post-embryonic differentiation and growth occur." The characters considered are (a) the number of leaves per whorl; (b) the position of the whorl on the plant; (c) the size of the various divisions of the plant; and (d) the position of the branches. It is found that the mean number of leaves per whorl is greatest on the main stem and decreases on the primary, secondary, tertiary and quaternary branches. The variability — measured by both the standard deviation and the cœfficient of variation, on the other hand, increases on the branches of the first and second order to fall again on those of the third and fourth order. The skewness also seems to increase in the negative direction from the main stem outward but the shortness of the material does not permit of the determination of this point by analytical methods beyond the secondary branches. A marked correlation is found between the position of the whorl on the stem and the number of leaves. The number of leaves increases from the base to the tip of the axis but the increase cannot be represented by the slope of a straight line — in biometric terminology, regression is not linear — or by a parabola. The increase is, however,

[1] Pearl, R. Variation and Differentiation in Ceratophyllum. *Carnegie Institution of Washington*, 1907, Publ. 58, 136 pp., 26 figs., 2 pl.

well represented by a logarithmic curve. This is the first law of growth in Ceratophyllum and may be stated as follows: "On any axial division of the plant the mean number of leaves per whorl increases with each successive whorl in such a way that both the absolute increment and the rate of increase diminish as the distance (in units of nodes) of the whorl from a fixed point increases."

The second law of growth is that of diminishing variability. The whorls of leaves produced by a growing point are formed with ever increasing fidelity to type. "The growing point appears to be influenced in its morphogenetic activity by its previous experience."

To the students of evolution, who are now concerning themselves primarily with experimental and statistical investigations of variation and heredity, the importance of such a detailed study of intra-individual variation, correlation and differentiation will be apparent. In the original paper they will find a wealth of analyzed material.

J. A. Harris

Cotton.— *Its Cultivation, Marketing, Manufacture, and the Problems of the Cotton World.* By Charles William Burkett, Professor of Agriculture, North Carolina College of Agriculture and Mechanic Arts, and Clarence Hamilton Poe.[1]— This volume of over three hundred pages is interesting from many points of view. Its illustrations are reproductions in a sepia tone of much effectiveness and the contrasts, especially in the case of white cotton bolls are very pleasing. Moreover many of the sketches are likely to be of permanent interest as matters of record, notably those which give some notion of fast-vanishing methods of carding, spinning, and weaving cotton by hand. The authors have spared no pains to make the illustrations attractive and useful, and they have succeeded admirably. The text is clearly written, throughout, and it is well-arranged with respect to convenience of reference. Moreover, the facts as regards the botany, the agriculture, and the commercial relations of the cotton-plant, are carefully stated in such a manner as to be quite within the reach of the general reader, but we miss what ought never to be lacking in any book of reference,— an index. The value of this useful treatise would be enhanced tenfold by a copious alphabetical and subject index.

G. L. Goodale

Notes. — Three new species of Dendromecon are described by Fedde in *Repertorium Novarum Specierum* of Jan. 15.

[1] New York, Doubleday, Page & Company.

Notes and illustrations concerning *Robinia Neo-Mexicana* are published by Phillips in *Forestry and Irrigation* for February.

An illustrated economic account of *Nyssa aquatica*, by von Schrenk, has been reprinted from the "Silver anniversary edition" of *The Southern Lumberman*.

Vaccinium Dobbini is the name proposed by Burnham in *The American Botanist* of February for a New York relative of *V. vacillans*.

A revision of Spilanthes, by A. H. Moore, constituting no. 33 of the new series of "Contributions from the Gray Herbarium of Harvard University," is published as vol. 42, no. 20 of the *Proceedings of the American Academy of Arts and Sciences*.

A paper on Citharexylum, by Greenman, forms *Publication 117* of the Field Columbian Museum.

On Pringle's Santa Catalina Mountain material of 1881, Dode bases a new *Juglans elæopyren* in the *Bulletin de l'Herbier Boissier* of February 28.

An economic account of the walnut in Oregon is published by Lewis in *Bulletin no. 92* of the Agricultural Experiment Station of that State.

A new Californian oak, *Quercus Pricei*, is described by Sudworth in *Forestry and Irrigation* for March.

Several new aloids and other succulents are described by Berger in vol. 4, no. 38 of the *Notizblatt des K. Botanischen Gartens und Museums zu Berlin*.

Agave deserti is figured in detail in *Icones Selectæ Horti Thenensis*, vol. 6, fasc. 1.

A series of notes on Abietineæ, by Hickel, are appearing in the *Bulletin de la Société Dendrologique de France*.

Cardot and Thériot report on a collection of 63 Alaskan mosses in vol. 2, no. 13 of the *University of California Publications, Botany*.

Vol. 7, part 2, of *North American Flora* is occupied with a part of the Uredinales, by Arthur.

An extensive and well illustrated paper by Lyman on "Culture Studies on Polymorphism of Hymenomycetes," constituting no. 64 of the "Contributions from the Cryptogamic Laboratory of Harvard University," forms vol. 33, no. 4 of the *Proceedings of the Boston Society of Natural History*.

An enumeration of the fungi collected by Simmons on the second Norwegian Polar expedition, by Rostrup, was published in no. 9 of the *Report* on the Expedition shortly before the death of the author, which occurred in January.

Several quite distinct puff balls and phalloids of Argentina are described and figured by Spegazzini in a paper recently distributed from vol. 16 of the *Anales del Museo Nacional de Buenos Aires.*

A flora of Central Europe, with text cuts and colored plates, by Hegi and Dunzinger, is being issued in 70 monthly parts from the Lehmann Press of Munich.

With vol. 3, fasc. 7, issued in December, Coste's "Flore Descriptive et Illustrée de la France" etc. was brought to a conclusion, the final signatures dealing with Pteridophytes.

An ecological systematic account of the flora of Columbia, Missouri, by F. P. Daniels, forms vol. 1, no. 2 of the Scientific Series of *The University of Missouri Studies.* Twelve new species or varieties and 26 new names occur in the list, which includes 13 genera, with 19 species, of Pteridophytes and 422 genera, with 1039 species, of Spermatophytes.

A general biological study of the sand areas of Illinois, by Hart and Gleason, forms vol. 7, article 7 of the *Bulletin of the Illinois State Laboratory of Natural History.*

The distribution and adaptation of the vegetation of Texas are discussed by Bray in *Bulletin no. 82* (Scientific Series no. 10) of the University of Texas.

A study of the flora of the Sand Keys of Florida, by Millspaugh, forms *Publication 118* of the Field Columbian Museum.

A further paper on the grasses of Argentina has been published by Stuckert in vol. 13 of the *Anales del Museo Nacional de Buenos Aires.*

The first fascicle of vol. 3 of Arechavaleta's "Flora Uruguaya" has recently been issued as a part of vol. 6 of the *Anales del Museo Nacional de Montevideo.*

Mr. Cook's concept of "Kinetic Evolution" is set forth in extenso in a large brochure of vol. 8 of the *Proceedings of the Washington Academy of Sciences,* issued on February 13th.

Separates of Dr. Robinson's paper on "The Problems of Ecology" have been distributed from vol. 5 of "*Congress of Arts and Sciences, Universal Exposition, St. Louis, 1904.*"

Studies on the pollination of Wisconsin flowers are being published by Graenicher in current numbers of the *Bulletin of the Wisconsin Natural History Society.*

Von Ihering contributes an illustrated account of the myrmecophilous Cecropias to recent numbers of Engler's *Botanische Jahrbücher.*

Dissemination by the aid of ants is the subject of a well illustrated memoir by Sernander, forming vol. 41, no. 7 of the *K. Svenska Vetenskapsakademiens Handlingar.*

A large preliminary paper on the fungi of certain termite nests, by Petch, is published, with illustrations, in vol. 3, part 2 of the *Annals of the Royal Botanic Gardens, Peradeniya.*

A comprehensive bibliographic, botanical and physiological memoir on tannoids, by Dekker, forms no. 35 of the *Bulletin van het Koloniaal Museum te Haarlem,* printed in December last.

A long list of plants known to contain prussic acid is separately distributed by Greshoff from the 1906 *Report of the British Association for the Advancement of Science.*

Studies on the influence of spectral colors on the sporulation of Saccharomyces are reported by Purvis and Warwick in vol. 14, part 1 of the *Proceedings of the Cambridge Philosophical Society.*

The root-knees of Sonneratia are well figured in the *Annual Report of the Director of Forestry of the Philippine Islands for the Period July, 1905 to June 30, 1906.*

A rope-like tumor of *Betula populifolia* is described and figured by Penhallow in a separate from vol. 12 of the *Transactions of the Royal Society of Canada.*

An illustrated account of commercial seeds of brome grass and blue grass and their adulterants, by Roberts and Freeman, forms *Bulletin 141* of the Kansas Agricultural Experiment Station.

Tobacco breeding is considered by Shamel and Cobey in *Bulletin no. 96* of the Bureau of Plant Industry, U. S. Department of Agriculture.

An illustrated editorial account of the Mexican "guayule" is being published in current numbers of *The India Rubber World.*

A discussion of timber under conditions of modern demand and growth, by von Schrenk and others before the New England Railroad Club, has been distributed in pamphlet form by the Rand Avery Supply Company of Boston.

A series of "Forest Planting Leaflets," each dealing with a single species, is being published as *Circulars of the Forest Service* of the United States Department of Agriculture.

Studies of the wood of Javan trees, by Moll and Janssonius, are being published by the Brill Press of Leiden.

A second edition of the useful "Key to the Genera of Woody Plants in Winter," by Wiegand and Foxworthy, has been issued by the authors, whose address is Ithaca, N. Y.

A portrait, with short biographic sketch, of the late Sir Thomas Hanbury is given in The *Gardeners' Chronicle* of March 16th.

A portrait of H. N. Ridley is given in *Tropical Life* for January.

An appreciative notice of Marshall Ward, by the late Director of Kew Gardens, appears in *The New Phytologist* of January 31.

Fascicle 4 of de Wildeman's "Enumération des Plantes Récoltées par Emile Laurent," issued in February, contains a portrait and biographic sketch of Laurent.

Further articles on Burbank and his work, by DeVries, appear in the *Biologisches Centralblatt* for September, *The Open Court* for November, and *The Century Magazine* for March.

W. T.

GEOLOGY.

The Elements of Geology.[1]— Professor Norton of Cornell College, Iowa, has sought to present to the public an elementary textbook on geology "in which causes and their consequences should be knit together as closely as possible." He accordingly departs from the usual three-fold division into dynamical, structural, and historical geology, treating geological processes and the forms or structures which they produce in immediate connection, under the headings "External Geological Agencies" and "Internal Geological Agencies." A third part of the book treats of Historical Geology.

Under the heading "External Geological Agencies" the work of

[1] Norton, William Harmon, *The Elements of Geology.* Boston, Ginn & Company. x + 462 pp., 374 illustrations.

the weather and the work of ground water are first considered, after which the work of rivers, glaciers, winds, and the sea are considered in the order indicated. A final chapter in this part of the book discusses off-shore and deep-sea deposits. Under the heading "Internal Geological Agencies" the following chapters appear: Movements of the Earth's Crust, Earthquakes, Volcanoes, Underground Structures of Igneous Origin, Metamorphism and Mineral Veins. Historical Geology is treated in the usual manner, the principal systems and some of their characteristic fossils being described in order, beginning with the Pre-Cambrian. Special emphasis is laid upon the evolution of the North American continent and the evolution of life upon the planet.

It is probable that many will doubt the wisdom of dropping out structural geology as a special subject and treating it only in connection with geological processes. There are difficulties in the way of such a treatment, one being the danger that the elementary student will not discriminate sufficiently between the process, the structures due to the process, and the structures which merely affect the operation of the process, all of which are treated under a single tit e. In the present text this danger is minimized by a clear presentation of the different factors involved, although in places a stronger discrimination between structures due to the process under discussion and structures controlling the operation of that process might profitably have been made.

The illustrations are well chosen and remarkably good. Indeed, Professor Norton's book is one of the best illustrated elementary texts on geology which the reviewer has seen. The book is thus made attractive to the student, and at the same time the subjects treated are made more real to him than is possible with inferior illustrations. In view of the fact that contour maps are used for some of the figures, it would doubtless increase the efficiency of the book to have the printed explanation of contours on page 69 supplemented by such illustrations as would aid the student to a better understanding of that subject than the brief printed text is apt to impart

As is the case with every text, there are points in Professor Norton's book which one would prefer to see changed. But after a careful reading the reviewer is convinced that the author has succeeded in his endeavor to present a text which will rank as one of the best elementary treatises on geology. The mechanical work on the book is excellent.

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Bergen, J. Y. and Davis, B. M. *Laboratory and Field Manual of Botany.* Boston, Ginn & Company, 1907. 12mo, 257 pp. 90 cents.— Bigelow, E. F. *The Spirit of Nature Study.* New York, A. S. Barnes & Company, 1907. 222 pp., illus.

Appellöf, A., *editor.* Meeresfauna von Bergen, parts 2 and 3 (Bryozoa and decapod Crustacea), pp. 76–233, 4 pls., 3 maps. *Publ. of the Bergen Museum,* 1906.— Chevreux, Ed. Orchomenella lobata, nouvelle espèce d'Amphipode des régions arctiques. *Bull. de l'Inst. Oceanog. de Monaco,* no. 96, 6 pp., 3 figs.— Cobb, N. A. Some elements of plant pathology. *Rep. of the Exp. Sta. of the Hawaiian Sugar Planters' Assoc., div. of path. and p ys.,* bull. 4, 46 pp., 32 illus. — Coutière, H. Questionnaire relatif aux espèces comestibles de Crustacés. *Bull. de l'Inst. Oceanog. de Monaco,* no. 98, 8 pp.— Fernald, H. T. The San José scale and experiments for its control. *Mass. Agric. Exp. Sta.,* bull. 116, 22 pp.— Forbes, S. A. On the local distribution of certain Illinois fishes. *Bull. of Ill. State Lab.,* vol. 7, art. 8, pp. 273–303, pls. 24–32, 15 maps.— Forbes, S. A. An ornithological cross-section of Illinois in autumn. *Bull. of Ill. State Lab.,* vol. 7, art. 9, pp. 305–335.— Franklin, H. J. Preliminary report on cranberry insects. *Mass. Agric. Exp. Sta.,* bull. 115, 15 pp.— Grinnell, J. and H. W. Reptiles of Los Angeles County, California. *Throop Inst. Bull.,* no. 35, 60 pp., 23 figs. Hodge, F. W., *editor.* Handbook of American Indians north of Mexico part 1. *Smithsonian Inst., Bur. of Amer. Ethn.,* bull. 30, 972 pp., illus.— Johannsen, W. Om "Kortskaller" og "Langskaller." *D. K. D. Vid. Selsk. Overs.,* no. 1, 72 pp.— Jordan, D. S. A review of the fishes of the family Gerridae found in the waters of Japan. *Proc. U. S. Nat. Mus.,* vol. 32, pp. 245–248, 2 figs.— Kofoid, C. A. Dinoflagellata of the San Diego region, III. Descriptions of new species. *Univ. of Cal. Publ., Zool.,* vol. 3, no. 13, pp. 299–340, pls. 22–33.— Mearns, E. A. Mammals of the Mexican boundary of the United States, part 1. *Smithsonian Inst., U. S. Nat. Mus.,* bull. 56, 501 pp., 126 figs., 1 map.— Merrill, G. P., and Tassin, W. On the meteorite from Rich Mountain, Jackson County, North Carolina. *Proc. U. S. Nat. Mus.,* vol. 32, pp. 241–244, pl. 16.— Porter, P., and Richard, J. Sur une méthode de prélèvement de l'eau de mer destinée aux études bactériologiques. *Bull. de l'Inst. Oceanog. de Monaco,* no. 97, 4 pp., 4 figs.— Sars, G. O. An account of the Crustacea of Norway, vol. 5, parts 13–16 (Copepoda: Diosaccidæ and Canthocamptidæ), pp. 157–196, 32 pls.) *Publ. of the Bergen Museum,* 1906.— Starks, E. C. and Morris, E. L. The marine fishes of southern California. *Univ. of Cal. Publ., Zool.,* vol. 3, no. 11, pp. 159–251, pl. 21.— Vaughan, T. W. Some madreporarian corals from French Somaliland, East Africa, collected by Dr. Charles Gravier. *Proc. U. S. Nat. Mus.,* vol. 32, pp. 249–266, pl. 17–28.— Vernon, J. J. Dry farming in New Mexico. *N. M. Agric. Exp. Sta.,* bull. 61, 54 pp., 30 pls.— Williams, H. S.

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A new Brachiopod, *Rensselæria mainensis*, from the Devonian of Maine. *Proc. U. S. Nat. Mus.*, vol. 32, pp. 267–269.

Annales de la Société Belge de Microscopie, vol. 27, no. 2, 1906; vol. 28, no. 1. Annual announcement of the Marine Biological Laboratory, Woods Hole, Mass. Bergens Museum Aarbog 1906, nos. 1 and 2. Bulletin of the Charleston Museum, vol. 3, no. 3. Bulletin of the Torrey Botanical Club, vol. 34, no. 2. Journal of Geography, vol. 6, no. 1. Naturæ Novitates, vol. 29, nos. 1–3. Ohio State University Bulletin, vol. 11, no. 9, supplement B. President's report of the University of Montana, 1905–1906. Proceedings of the Washington Academy of Sciences, vol. 8, pp. I–XIII, 487–491. Staten Island Association of Arts and Sciences, vol. 1, part 3, 1906, and memorial number, 1907. University of Colorado, Studies, vol. 4, no. 2.

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